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THE UNIVERSITY OF ALBERTA

THE EFFECT OF TEMPERATURE ON THE SHEAR STRENGTH OF TWO EDMONTON CLAY SOILS

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

DEPARTMENT OF CIVIL ENGINEERING

by

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EDMONTON, ALBERTA

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UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled 'The Effect of Temperature on the Shear Strength of Two Edmonton Clay Soils' submitted by Walter Semchuk in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

An investigation of the effect of temperature on the shearing strength of two locally obtained clay soils has been carried out. The strengths were determined by means of consolidated undrained triaxial compression tests with measurement of pore pressure. The tests were carried out on remoulded samples at two different temperatures. One series of these was conducted at a temperature of about 35°F and the other at room temperature.

A description of the apparatus developed, to obtain and maintain the low temperature in the triaxial cell, together with the method of continuous recording of this temperature has been presented. The experimental procedure has been described in considerable detail mainly because there is as yet no standardized procedure for carrying out the triaxial test with pore pressure measurement.

For both of the soils investigated, a clay of high plasticity and a silty clay of low plasticity, it was found that the effect of temperature on the angle of shearing resistance is probably smaller than the experimental error inherent in the testing apparatus and therefore temperature is a difficult variable to study. However it appears that there is some loss in cohesion with a decrease in temperature.

It was found that the apparatus developed for the

low temperature tests is satisfactory in principle. However, the variation from a low to a high temperature in the series at low temperature could not be controlled to a smaller amount than that observed for the tests at room temperature. Hence any future work with the developed equipment requires further refinement to the temperature control mechanism.

ACKNOWLEDGEMENTS

This investigation has been carried out under the direction of Professor S. R. Sinclair and the thesis prepared under the guidance of Professor S. Thomson. The writer is indebted to both of these people for their guidance and criticisms.

The author wishes to express his sincerest appreciation to Professor Thomson who gave so freely of his time in teaching the techniques of the triaxial test to the writer, and for the generous use of his personal library.

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SYMBOLS

$\bar{A}$	Pore pressure coefficient which equals the percentage of an applied deviator stress that is transmitted to the pore water within a sample
A_T or A_t	Cross-sectional area of the top of a triaxial test specimen
A_C or A_c	Cross-sectional area of the centre of a triaxial test specimen
A_B or A_b	Cross-sectional area of the bottom of a triaxial test specimen
e	Void ratio
e_f	Void ratio at failure
c	Cohesion, total stresses
c'	Cohesion, effective stresses
s or τ	Shear strength
S_f	Degree of saturation at failure
W	Moisture content
W_i	Initial moisture content or moisture content prior to triaxial consolidation
W_f	Moisture content at failure
μ	Axial strain

t_{100}	Time for theoretical 100% consolidation
σ	Total normal stress
σ'_f	Effective normal stress on plane of failure at failure
σ_c	Confining pressure in triaxial cell
σ_1	Total major principal stress
σ_3	Total minor principal stress
σ'_{1f}	Effective major principal stress at failure
σ'_{3f}	Effective minor principal stress at failure
ϕ	Angle of shearing resistance, total stresses
ϕ'	Angle of shearing resistance, effective stresses

CHAPTER I

INTRODUCTION, PURPOSE AND SCOPE OF THE INVESTIGATION

Introduction

Ever since soil mechanics came into being as a science, some 37 years ago, the object of a great number of research workers has been the search for a correct formulation of the shearing strength of cohesive soils. The rapid development of shear testing equipment and testing technique, coupled with the enunciation of the principle of effective stress, has paved the way to a better understanding of the strength and deformation characteristics of these soils.

Credit for the expression of shear strength of cohesive soils in terms of mathematical expressions of the results of shear tests, called physical or phenomenological components, is accorded Hvorslev. See Terzaghi (40)*, Bjerrum (5). One component, 'true cohesion', was found to be a function of the moisture content of the clay. The other component was known as the 'true angle of internal friction'. These components were believed to be fundamental physical properties for a given clay soil. However, in view of the possibility that research into the physicochemical properties of clays may suggest modifications to these components,

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*Numbers in parenthesis refer to references in the Bibliography.

Hvorslev (17) prefers the terms 'effective angle of internal friction' and 'effective cohesion' rather than 'true angle of internal friction' and 'true cohesion'.

The difficulty in determining these physical components has precluded their use in stability analysis and today the failure criterion expressing the shearing strength of cohesive soils, and enjoying the widest general applicability, is obtained by expressing the shear strength as a function of the effective normal stress. This is in accordance with Terzaghi's fundamental concept that the strength and deformation characteristics of soils are governed by the effective stresses rather than the total stresses in a soil mass.

The effective stress concept is empirical in nature but its practical validity has been demonstrated by many field observations*. It is expressed in the form of Coulomb's original hypothesis as:

$$^{**}\tau_f = c' + \sigma_f' \tan \phi'$$

It is important to note that the parameters c' and ϕ' are the cohesion and angle of shearing resistance respectively, in terms of effective stress, in contradistinction to Hvorslev's physical components of effective cohesion and effective angle of internal friction. Neither Hvorslev's expression for the shearing strength of cohesive soils nor the

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*A more detailed discussion in this regard will be found in reference (34).

**See the list of symbols for definition of the terms.

effective stress concept is unique in expressing the shearing strength of these soils. Furthermore, stability analyses, in terms of the effective stress concept, often result in unrealistic values of the factor of safety, when performed on highly over-consolidated clays, Hardy et al (14), Bishop (34). Hence clarification of the physicochemical constitution of clays and of the intrinsic forces believed to be active between particles in a soil-water system is of utmost importance to a better understanding of the strength properties of clay soils.

As early as 1925 workers in soil mechanics were aware of the existance of surface electrical charges on colloidal sized clay particles, Terzaghi (39). In this reference can be seen diagrams of a honeycombe structure for sedimented clays, as a result of these surface charges. In the past decade there has been a large impetus into the inquiry of the mechanism of shear strength mobilization in terms of the physicochemical approach, by workers in the field of soil mechanics. Among the papers dealing with this subject reference can be made to Lambe (20), (21), (22), (23), Seed, Mitchell, and Chan (34), Rosenquist (31), (32), and Olson and Mitranovas (28).

It has been suggested that temperature, among other variables, may play an important role in the mobilization of shear strength in cohesive soils*. The effect of temperature

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*Further details are contained in references (21) and (23).

change on the shearing strength of cohesive soils is not as yet well understood and as will be seen in Chapter II is still a controversial issue. It is known, however, that there can be a large disparity of temperatures between in-situ soil conditions and that in the laboratory. The practical significance of this difference in temperature has suggested the topic for this investigation.

It has been established that there exists a sink point* below which variations in temperature are small. Johnson (18) cites Bouycous who attributes the factors which influence soil temperature as those which are internal and those which are external. In the former case the factors are those contained by the soil and include the specific heat, heat conductivity, radiation, water content, density, evaporation of water, topographic position, etc. In the latter case the factors are comprised of the meteorological elements and include air temperature, sunshine, wind, precipitation, etc.

The array of variables is formidable, nevertheless, Crawford (9) cites the results of several workers with regard to seasonal temperature variation with depth. Specifically Thompson at Winnipeg, Manitoba, observed that at a depth of 15 feet below ground surface, seasonal temperature varied $4^{o}F$

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*The depth below ground line at which there is no apparent response in ground temperature to the variation in surface air temperature.

(averaged over a three year period), and presumed that no variation would occur at a depth of 20 feet even though the extreme air temperature range was found to be 140°F in this region. At Minneapolis, Algren deduced that the annual variation in temperature at a depth of 28 feet would be 2°F, with an average temperature of 50°F at this depth. At Montreal, Callendar and McLeod found an annual temperature range of 11°F at a depth of 9 feet in a turf covered area of loose sand. Lauchli, in Georgia observed a constant temperature of about 61.5°F at a depth of 45 feet. Rambout at Oxford, England, observed a range of 9.5°F at a depth of 10 feet in a gravelly soil with grass cover.

The inference, drawn by Crawford (9), from these observations is that in temperate climates there is little variation in temperature at a depth of 25 feet below ground surface and that the average temperature is reasonably close to 50°F.

Purpose of the investigation.

Lambe (19) has suggested that a temperature variation of from 70°F to 95°F is reasonable for a laboratory. In Edmonton the upper limit of temperature would probably not exceed 85°F. This is considerably higher than the temperature at the sink point, yet tests are performed at room temperature on samples often recovered from depths below this level.

There have been some investigations made into the effect of temperature change on the Atterberg Limits,

consolidation characteristics, and compaction of clay soils, Casagrande (19), Youssef et al (44), Gray (13), Finn (10). The effect of this variable on the shear strength of clay soils has received comparatively less attention. The published data is mostly qualitative and conflicting. The strength tests which have been performed were either laboratory unconfined compressive strength tests or laboratory vane strength tests. To date, August 1962, there has not been any published data on the results of triaxial compression tests, in terms of effective stress, with variation in temperature, found by the writer after an exhaustive search.

Accordingly, the purpose of this investigation was to examine the effect of temperature change on the shear strength characteristics, in terms of the concept of effective stress, on two locally obtained clay soils.

Scope of the investigation.

Two series of consolidated undrained triaxial compression tests with pore pressure measurements were run on remoulded samples of two distinctly different clay soil types at two different temperatures. One was a highly plastic clay and the other was a silty clay of low plasticity*.

One series of triaxial tests was performed at a temperature slightly above the freezing point of water on each soil type. This temperature was chosen so as to

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*Unified classification system.

magnify the possible effect of this variable when compared with the second series of tests which was run at room temperature.

Augmenting the triaxial tests a limited amount of one-dimensional consolidation tests were carried out on the same soil types to study the temperature effects on the consolidation characteristics.

CHAPTER II

LITERATURE REVIEW

Published data on the effect of temperature on the shear strength of clay soils is meager and there is a difference of opinion among several authorities as to the effect of this variable.

Lambe (21) in his paper on clay structure in terms of colloid and crystal chemistry states:

> 'Any change in the soil-water system which expands the double layer tends to decrease soil strength (at a given void ratio), since interference by the double layers of two adjacent colloids increases interparticle repulsion. This concept leads to the prediction that any of the following changes would generally reduce the shear strength of a clay:
>
> 1. Reduction of electrolyte concentration
> 2. Cation exchange from high to low valence (e.g. Ca^{++} to Na^{+})
> 3. Adsorption of phosphate
> 4. Exchange from a cation of small hydrated radius to a cation of large hydrated radius (e.g. Na^{+} to Li^{+})
> 5. Increase of dielectric constant of pore fluid
> 6. Increase of pH of pore fluid
> 7. Decrease of temperature
> 8. Increase in water content
>
> The influence of some of these eight changes has been investigated. Bjerrum and Rosenquist have, for example, conclusively shown that a reduction of electrolyte by leaching can reduce both the undisturbed and remolded shear strengths. The reduction of strength resulting from an increase in moisture is well known. The effect of some of the other changes, e.g. temperature, has yet to be thoroughly investigated.'

Leonards (24) in a discussion of the above paper

by Lambe, suggests that the structure of the water in the diffuse double layer surrounding clay particles, plays an important role in the behaviour of soil-water systems. He is of the opinion that there exists a very strongly developed water structure in the immediate vicinity of a clay particle surface, that this structure is different from that in ice, and that it influences the shearing resistance of clays. He cites several references which indicate that the opposite condition from that stated by Lambe was found to hold. That is, a decrease in temperature results in an increase in strength. One of these references is the work of Hogentogler and Willis (16), in which the effect of temperature on the moisture content, dry density, and stability (as measured by the plasticity needle), on certain soils compacted in the same manner, were investigated. The soils tested had liquid limits ranging from 27% to 78% and plasticity indices ranging from 7% to 55%. The temperatures at which compaction tests were run were 35°F, 75°F, and 115°F. In all cases the dry density increased and the optimum moisture content decreased with increasing temperatures, for the same compactive effort. Stability tests, of each clay type were also performed on samples compacted at a temperature of about 125°F, and at a moisture content corresponding to the respective optimum values at 35°F. The temperature was then progressively lowered to about the freezing point. A considerable increase in stability, as measured with a plasticity needle, was

observed, the largest increase being from 1,400 psi to 2,000 psi. The authors explain the observed phenomenon as follows:

> 'Decrease in the temperature at constant moisture content causes a decrease in the free water and a corresponding increase in the adsorbed water*. This decrease in the ratio of the lubricating to the adhesive moisture results in an increase in the relative viscosity of the total moisture, adsorbed and free. This increase is in addition to the increase in the viscosity of the free water caused by drop in temperature. The total variation in the viscosity of all contained moisture can be considered as the primary influence on the variation in density and stability with variation in the temperature of compacted soils.'

Another reference cited by Leonards (24) is the work of Rosenquist (31). The postulation is made that the double layer surrounding clay particles consists of a thin film of tightly bound water while the other portion of this double layer water has properties very nearly the same as that of ordinary water. As the temperature is increased more and more of the solid water around the clay minerals passes into the liquid state resulting in a decrease in strength. The following evidence is presented by Rosenquist (31) to support this postulate:

> 'Experiments on the shear strength of clays seem to indicate that the shear strength of a given clay sample decreases with increasing temperatures.

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*The soil particle is envisioned as being encased in a film of adsorbed water, or water of hydration, and suspended in a body of free water. The properties of the outermost layer of this adsorbed film are more nearly like those of free water, and the properties of the innermost layer are more nearly like those of solidified water or ice.

> This is certainly the case with remoulded clays, but even with undisturbed clay samples we have found this same dependency, although it is always difficult to state with certainty how the shear strength of an undisturbed sample varies, as we can never use the same sample twice. By means of laboratory vane tests it has been possible to perform determinations of the shear strength at close vicinities.'

Unfortunately there are no quantitative results given in this paper.

Leonards and Andersland (25) present experimental evidence with regards to temperature change and unconfined compressive strength for two compacted clay soils. In the unfrozen state there is a small increase in the unconfined compressive strength with a decrease in temperature. Upon further cooling there is a marked increase in strength, the rate of gain in strength decreasing with decreasing temperature. The gain in strength from a temperature decrease from about 14°C to 0°C is very small and nearly imperceptible from the plots presented.

Lambe (23) presents the first evidence of the effect of temperature variation, in terms of a laterally confined triaxial test, which was found in the literature. In the test performed a sample of saturated plastic clay was sheared to failure in a triaxial test, at which point the temperature was reduced. The following data was obtained:

Temperature °C	Minor effective principal stress kg/cm^2
25	0.260
22.3	0.300
18	0.348
13	0.375

This data shows that there is a reduction in pore pressure with a decrease in temperature. However, details as to the exact nature of the test are lacking and it does not disclose the overall effect upon the measured shearing strength.

From the review of the literature it appears that the effect of temperature decrease is to increase the shearing strength of cohesive soils, but that this increase may not be large. It is also apparent that quantitative experimental evidence, with regard to this variable, is very meager.

CHAPTER III

TESTING PROGRAMME, SOILS STUDIED, AND APPARATUS

Testing programme.

The laboratory investigation involved primarily the performance of consolidated undrained triaxial compression tests with pore pressure measurements on remoulded clay specimens. Twenty four such tests were carried out; the results of three tests were rejected due to equipment malfunction. One half of the tests were carried out at a temperature slightly above the freezing point and the other half at room temperature. For the remainder of this report these temperatures will be known as low and high temperatures respectively. Two distinctly different clay soils were investigated; the first being a highly plastic clay, in which case it was hoped that the effect of temperature should be accentuated, and the second soil was a silty clay of low plasticity in which case the effects of temperature should be less pronounced.

In addition standard one-dimensional consolidation tests were run on both of the soils remoulded at the same initial moisture content as that for the triaxial test series.

For the triaxial tests at low temperature, hydrostatic consolidation, preceding the compression portion of the test, was performed at the low temperature. This was done for two reasons; first to study three-dimensional

consolidation characteristics at reduced temperature and the second reason was to allow enough time for the physicochemical changes to take place, prior to the shearing portion of the sample.

The following classification tests were carried out on the soils investigated, Specific Gravity D854-52, Liquid Limit D423-54T, Plastic Limit D424-54T, and Grain Size Analysis D422-54T, in accordance with the procedures for testing soils outlined by the American Society for Testing Materials. The results of these tests are summarized in Table 1, following a description of the soils investigated. A clay mineralogical composition was also performed, on the soils used, by the Alberta Research Council, and the results of this analysis are also given in Table 1.

Soils studied.

As previously mentioned two clayey soils were studied in this investigation, one was a clay of high plasticity and will be known as a C H Edmonton clay for the purposes of this thesis. The other soil was a glacial till of low plasticity and will be known henceforth as an Edmonton till.

The C H Edmonton clay was obtained from a highway cut located on the southern outskirts of Edmonton. The cut was opened during the summer of 1959 and the samples were dug out of the bank at a spot that would be approximately 15 to 20 feet below the original ground surface, in the early part

TABLE 1

SUMMARY OF CLASSIFICATION TESTS ON C H EDMONTON CLAY AND EDMONTON TILL

Test	Soil	
	C H Edmonton Clay	Edmonton Till
Specific Gravity	2.80	2.71
Atterberg Limits		
Liquid Limit	74.3	34.5
Plastic Limit	30.8	17.7
Plasticity Index	43.5	16.8
Grain Size Distribution*		
% Sand Sizes	4	42
% Silt Sizes	34	33
% Clay Sizes	62	25
Mineralogical Composition**		
Montmorillonite	30% to 40%	30% to 40%
Illite	30% to 40%	30% to 40%
Chlorite	20% to 30%	15% to 20%

*MIT grain size scale.

**Rough approximation only; furnished by Research Council of Alberta. On clay size fraction only.

of 1960. The soil was stored in the soils storage room until its use in this programme.

The Edmonton till, a light brown colored silty clay, was removed from the side of an open trench at the north west corner of the Engineering building on the University campus. It was removed from a depth of some 20 to 25 feet below the existing ground surface. The material contained rock fragments of gneiss, granite, and quartzite ranging in size from about 1/8 inch to 1/2 inch. These particles were sub-angular to angular in shape, indicative of glacial deposition.

Preparation of the soil.

(a) C H Edmonton clay.

About 10,000 grams of this air dried material was broken down to a minus No. 4 sieve size* by means of a heavy steel roller. This material was then further reduced in size by means of a disc type grinder located in the Department of Soil Science. After this grinding the soil was again sieved, the minus No. 40 fraction being reserved for testing, while the material retained being further reduced in size by means of the steel roller. This procedure was repeated until enough of the fine fraction was obtained for testing purposes. About 8,000 grams of the minus No. 40 fraction was then placed in a large round bottomed container and thoroughly mixed, to ensure uniformity. The total sample was then divided by means of a

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*U. S. Bureau of Standards sieve series.

sample splitter; one half reserved for the triaxial tests and the other half kept for classification and consolidation tests. Each portion of the sample was then again thoroughly mixed and stored in air-tight containers until needed.

(b) Edmonton till.

The raw sample was broken down quite easily into small lumps, then placed into shallow trays and allowed to dry for a period of one week. Portions of the air dried soil were then spread out on the soil preparation table and all of the larger sized rock fragments removed. This material was then reduced in size by means of a heavy steel roller and screened through a No. 40 sieve. The fine fraction was retained for testing and the coarser material retained was further reduced in size and sieved. This procedure was continued until sufficient material was collected for the testing programme. About 5,000 grams of the minus No. 40 material was then treated in a similar manner as that outlined above for the C.H. Edmonton clay.

Apparatus

The triaxial compression tests, were to be performed as consolidated undrained tests with measurements of induced pore pressure. Furthermore there would be a spread in temperature between the low temperature series and the one at room temperature of approximately 40°F. The first of these conditions requires a no-flow type of pore pressure measuring device and the second condition calls for a means

of developing and maintaining constant cell pressure even with large changes in temperature.

Both of the above mentioned requirements are fulfilled with the triaxial testing apparatus developed and now manufactured by the Norwegian Geotechnical Institute. Hence it was decided to use this type of equipment for the triaxial compression tests. Plate 1 is a general view of the apparatus used. A detailed description of this type of triaxial testing equipment will be found in references (2), (1), and (27).

Modification to triaxial cell.

Since it was impossible to use the triaxial equipment, described above, inside of a walk-in type of freezer, and thus effect temperature control, the idea was conceived of using an heat exchanger placed within the triaxial cell. This portion of the apparatus posed the major problem in the development of the testing equipment. It was decided to use a heat exchanger made of copper tubing, through which a thermally conditioned glycol-water mixture would be continuously circulated. It was not feasible to lead the ends of this copper coil through the top or bottom metallic plates of the triaxial cell, hence it was found necessary to lead them through the lucite chamber. To provide for leak proof joints at these tapping points, under the proposed working pressures, a Swagelak* type of fitting was used. However, in order to

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*Hoke General Catalogue, Part No. 600-1-OR.

accommodate this type of fitting a much heavier lucite chamber, than that normally used, had to be obtained. In the final modification a lucite chamber of 3/8 inch nominal wall thickness was used; the additional thickness being desirable from the point of view of added insulation.

In addition another tapping point had to be provided for in order that thermocouple leads could be brought through the chamber wall. This was successfully accomplished by modifying an ordinary 3/8 inch brass connector. Details of this modification are given in Figure 31 of Appendix III. A satisfactory water tight seal of the thermocouple lead wires was effected by means of a plastic filler material. Plate 2 is a photograph of the modified triaxial cell in service. During the course of testing a maximum cell pressure of 9.25 kg/cm^2 was used for periods up to 30 minutes and 8.25 kg/cm^2 for periods up to 24 hours. In only one instance was there any leakage observed, this being due to a loose connection, which when corrected gave rise to no further trouble.

In an effort to keep the heat loss to as low a value as possible a lucite disc 1/2 inch in thickness was machined to the dimensions shown in Figure 33 of Appendix III and placed on the bottom inside surface of the triaxial cell. Another disc was cut from a glass wool insulating material, to fit snugly against the bottom metallic plate of the triaxial cell and the table or the loading press upon which the cell sat. In addition, two pieces of an expanded vinyl plastic material

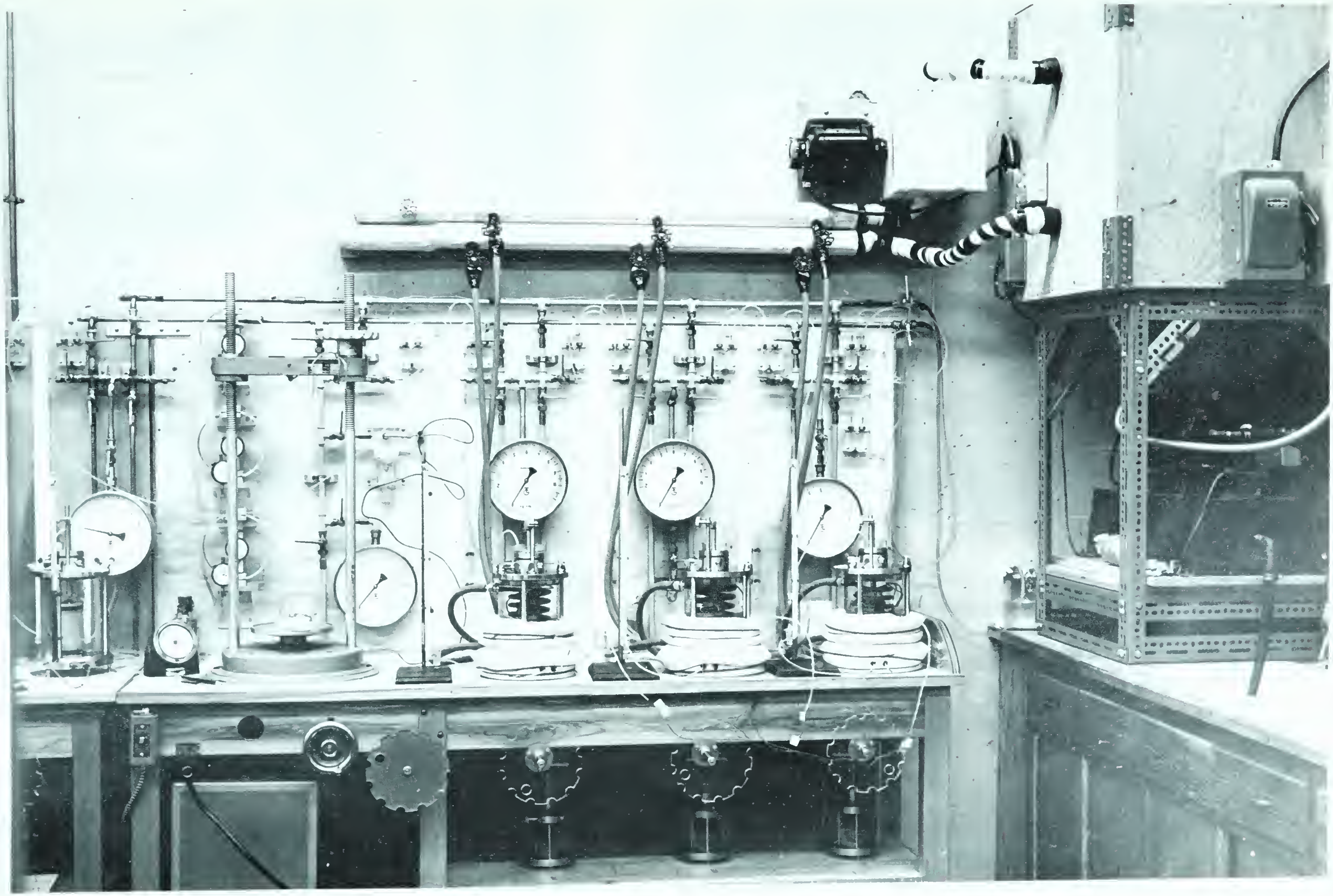

PLATE I

GENERAL VIEW OF TRIAXIAL TESTING EQUIPMENT

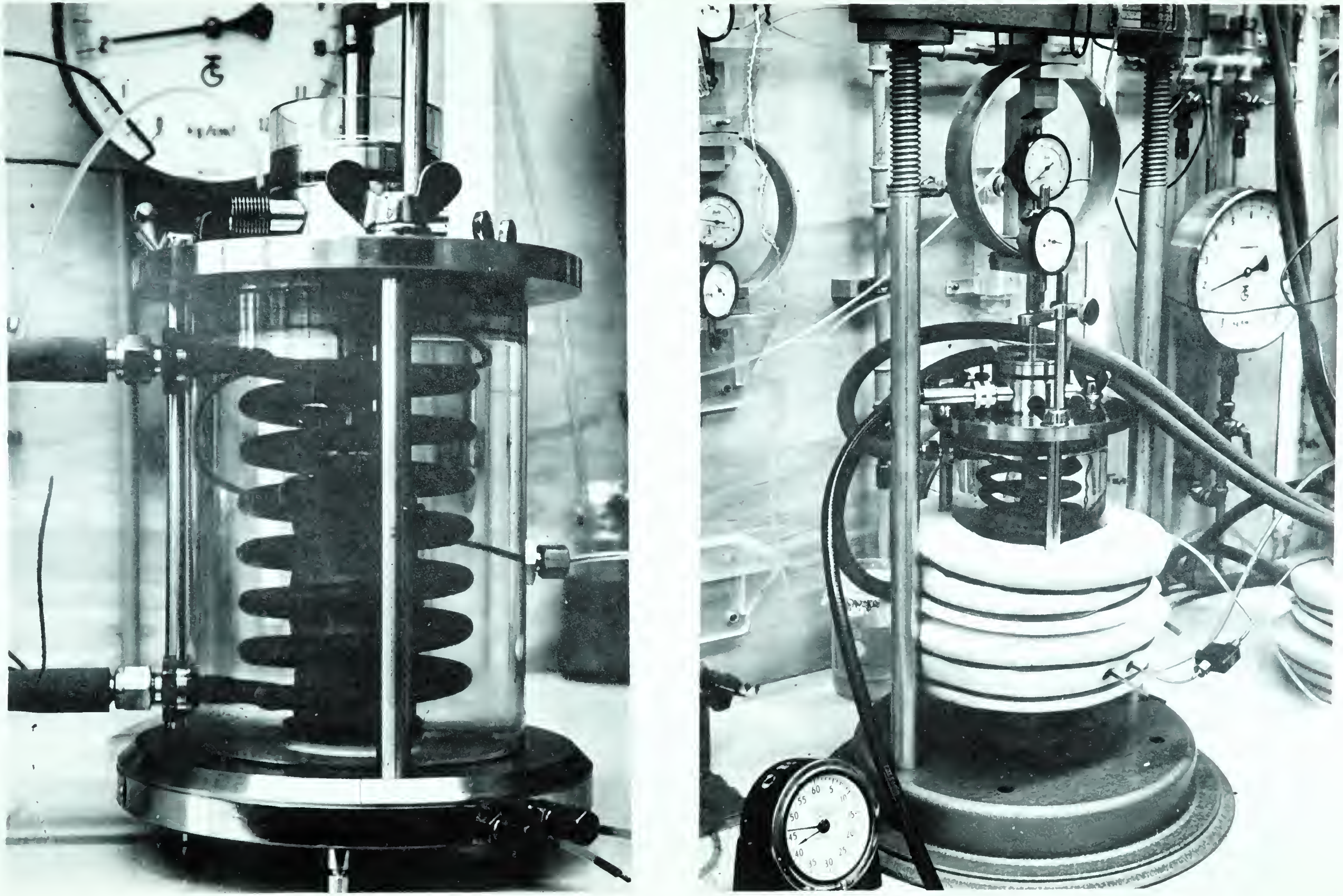

PLATE 2

MODIFIED TRIAXIAL CELL IN SERVICE

were wrapped around the lower portion of the assembled cell. These were held in place by means of heavy elastic strips. It was not possible to insulate the upper portion of the cell, by any external means, due to the complexity of the components in its assembly. However, a layer of oil (Teresso No. 65) about one inch thick was floated on the water, serving as the confining fluid, in each test in an effort to check heat exchange with the surrounding air.

A prototype cell was constructed and checked out as to performance, then two other such cells were modified to give a total of three. Detailed working drawings of the triaxial cell modification will be found on Figure 31 of Appendix III.

Cold tank, refrigeration unit and circulation system.

Plate 3 is a photograph of this portion of the apparatus. It consisted essentially of a large metal tank enclosed in a shell made of 1/2 inch thick plywood so as to provide for 2 3/8 inches of insulation. This tank contained the glycol-water mixture which was circulated through the triaxial cells after first being conditioned to the desired temperature. The mixture in the tank was cooled by means of copper coils in conjunction with a 1/2 ton commercial type compressor. The conditioned fluid was then circulated through a header line system by means of an impeller type pump*. Three drops, in parallel, were then taken off the

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*Jabsco, Model No. 3010-01.

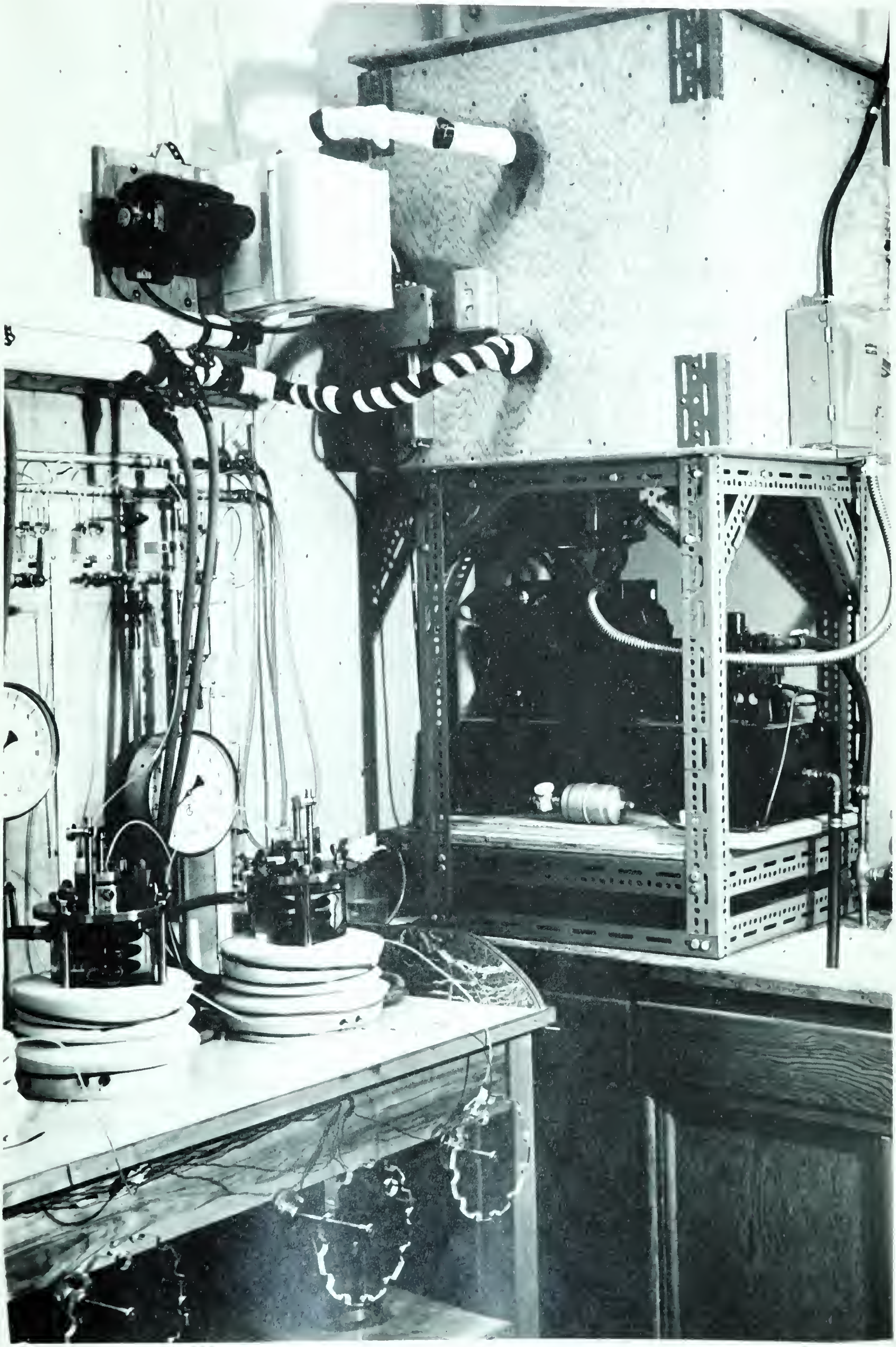

PLATE 3

VIEW OF COLD TANK, REFRIGERATION UNIT, AND CIRCULATION PUMP

header lines and thus circulation was effected into each triaxial cell. Figure 1 is a line diagram of the circulation system. Flow control valves* were placed on each drop; these valves were placed in the lines for control of circulation and for convenience of dismantling of the triaxial cells. As much of the circulation system as possible, including the pump, was insulated to help minimize heat exchange.

The tank was made of 1/16 inch thick galvanized iron with dimensions of 1'-9" x 1'-9" x 1'-9" with a resulting capacity of some thirty imperial gallons. It was found necessary to use a 1/2 H.P. heavy duty ball bearing type of electric motor to operate the neoprene impeller type circulation pump. Any motor smaller than this was found to become overheated when subjected to continuous operation for the periods of time required in this type of testing programme.

The refrigeration unit was automatically operated by means of a bi-metallic thermoswitch** in conjunction with a magnetic starter switch. This thermoswitch was situated in the cold tank, near the discharge point into the header line system.

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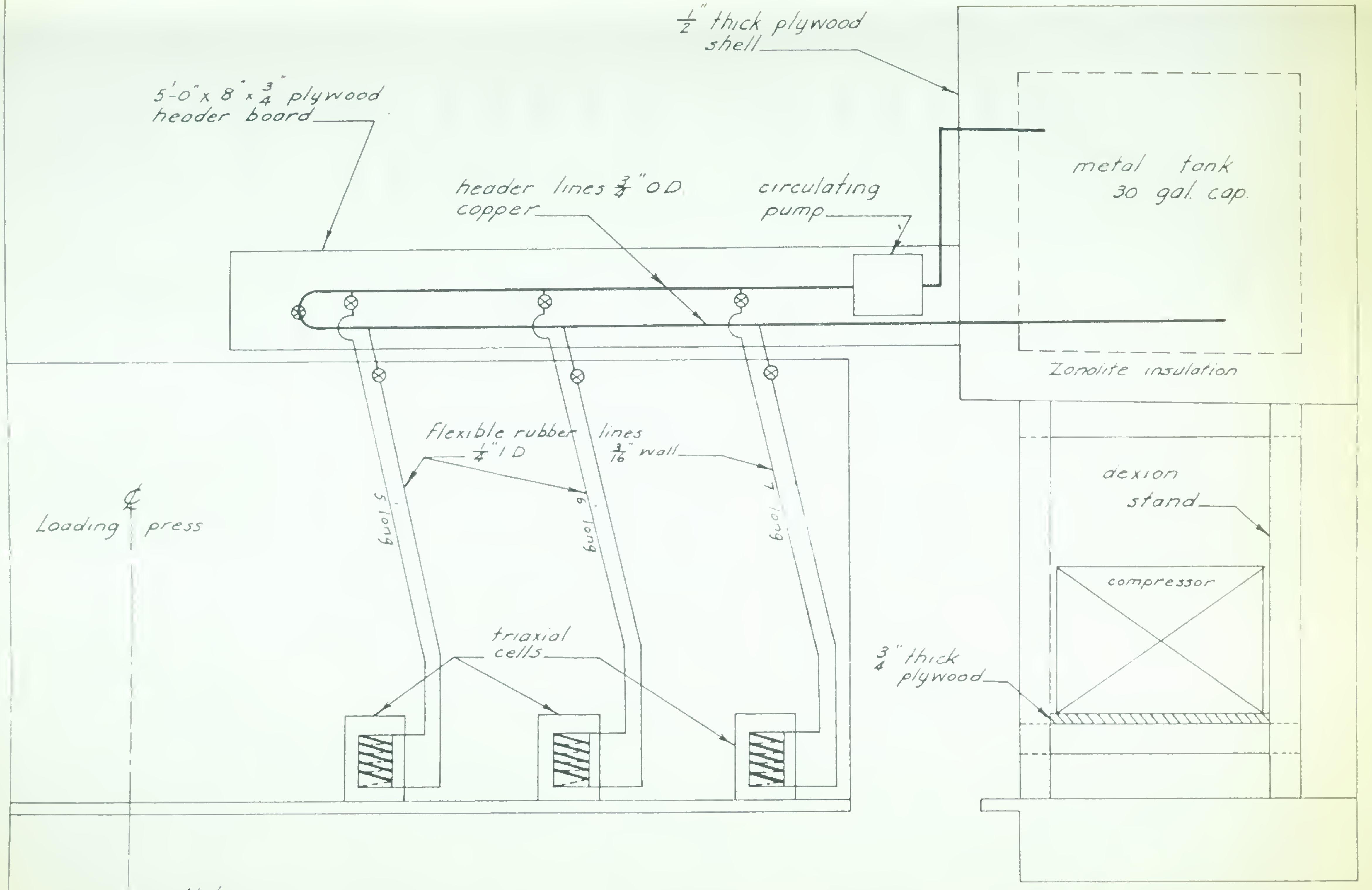
*Globe valve, Hoke General catalogue No. 1226.

**Thermoswitch Thermostat
Fenwal Inc., Ashland Mass.,
Rating 10A-115VAC, 5A-230VAC,
Contacts close on temperature rise.
Temperature range -100°F to 600°F.


$\frac{1}{2}$" thick plywood shell
5'-0" x 8" x $\frac{3}{4}$" plywood header board
header lines $\frac{3}{4}$" OD copper
circulating pump
metal tank 30 gal. cap.
Zonolite insulation
flexible rubber lines $\frac{1}{4}$" I D $\frac{3}{16}$" wall
5' long
6' long
7' long
Loading press
dexion stand
compressor
triaxial cells
$\frac{3}{4}$" thick plywood
Note header lines and pump insulated.

Line diagram of header lines and circulating system

Fig. 1

Temperature measurements.

Temperatures were measured and recorded with a Brown Electronic Strip Chart Recorder (Serial No. 534449, Model 153-X64P16 - X - 41), using iron constantan themocouples. The Thermocouples were made of No. 24B and S gauge wire, fused at one end by means of an oxy-acetylene flame. The bead so formed was then covered with a plastic type filler, to prevent corrosion. The recorder is capable of handling 16 such thermocouples, each point reading out at 4 minute intervals. The strip charts had a time scale as well as a temperature scale, this latter scale covering a range of from minus 50°F to plus 100°F.

All of the thermocouples used in this testing programme were calibrated by inserting them in a mixture of ice and water, stirring this mixture and observing its temperature and that recorded on the strip chart. The temperature of the ice-water mixture was observed by means of an ordinary laboratory mercury thermometer graduated in units of 0.1°C. Results of these calibrations are summarized in Table 15 of Appendix II, and have been applied to all temperatures recorded by means of the strip charts unless otherwise noted.

Modification to top loading cap.

In order to ascertain the relationship between the temperature within the soil specimen and the surrounding fluid it was necessary to place a thermocouple in the soil specimen. In order to do this it was necessary to make up a new top

loading head through which thermocouple leads could be brought and sealed. This loading cap was made up of a short piece of 1½ inch diameter lucite rod drilled out to accommodate the loading piston. Another small hole was drilled (No. 52 drill size) through this lucite in a vertical plane but at such an angle that a thermocouple of appropriate length would sit at the mid-point of a standard specimen when the loading cap was set in place. The thermocouple leads were sealed with a plastic filler which provided an adequate seal.

Another thermocouple was fixed into place, so that it would sit at the same relative height as that in the specimen, at a point mid-way between the inside surface of the cooling coils and the outer periphery of the soil sample. In this way it was possible to observe the relationship between the temperature of the surrounding fluid and that within the soil specimen.

This procedure was found necessary as it proved extremely difficult to assemble the cell with the modified loading cap not to mention the alterations to the strength characteristics which would have resulted because of the presence of the thermocouple wire leads. In addition the specimen was subjected to considerable rough handling in placing the modified top loading head. This triaxial cell was designated as the reference cell in the first series of tests at the low temperature. Thermocouples were also permanently fixed in the two other modified triaxial cells at the

same relative position as in the reference cell. The results of the testing in this manner are discussed fully in Chapter V.

CHAPTER IV

PROCEDURE

Moulding the Triaxial Test Specimens

The following procedure was employed in moulding all of the triaxial test specimens for both of the soil types investigated.

The total prepared soil, reserved for the compression tests, was divided up into 200 gram portions. To each of these portions distilled water was then added such that the moisture content was as close as practicable to the liquid limit. The soil and water was then thoroughly stirred, the container covered with aluminum foil and placed in the moist room for a period of from 14 to 16 hours.

Plate 4 is a photograph of the specimen moulding apparatus. Essentially it consists of a lucite cylinder 1 3/4" I.D., into which the moist soil is placed, this cylinder fitting into a larger water tight lucite cylinder. Three filter strips (Watman No. 54) were first placed onto the inner periphery of the smaller cylinder and placed in contact with a porous bronze drainage disc which fitted snugly into the lower end of this cylinder.

The soil paste was taken from the moist room thoroughly stirred once more and deposited in small quantities into the smaller cylinder by means of a spatula. This smaller

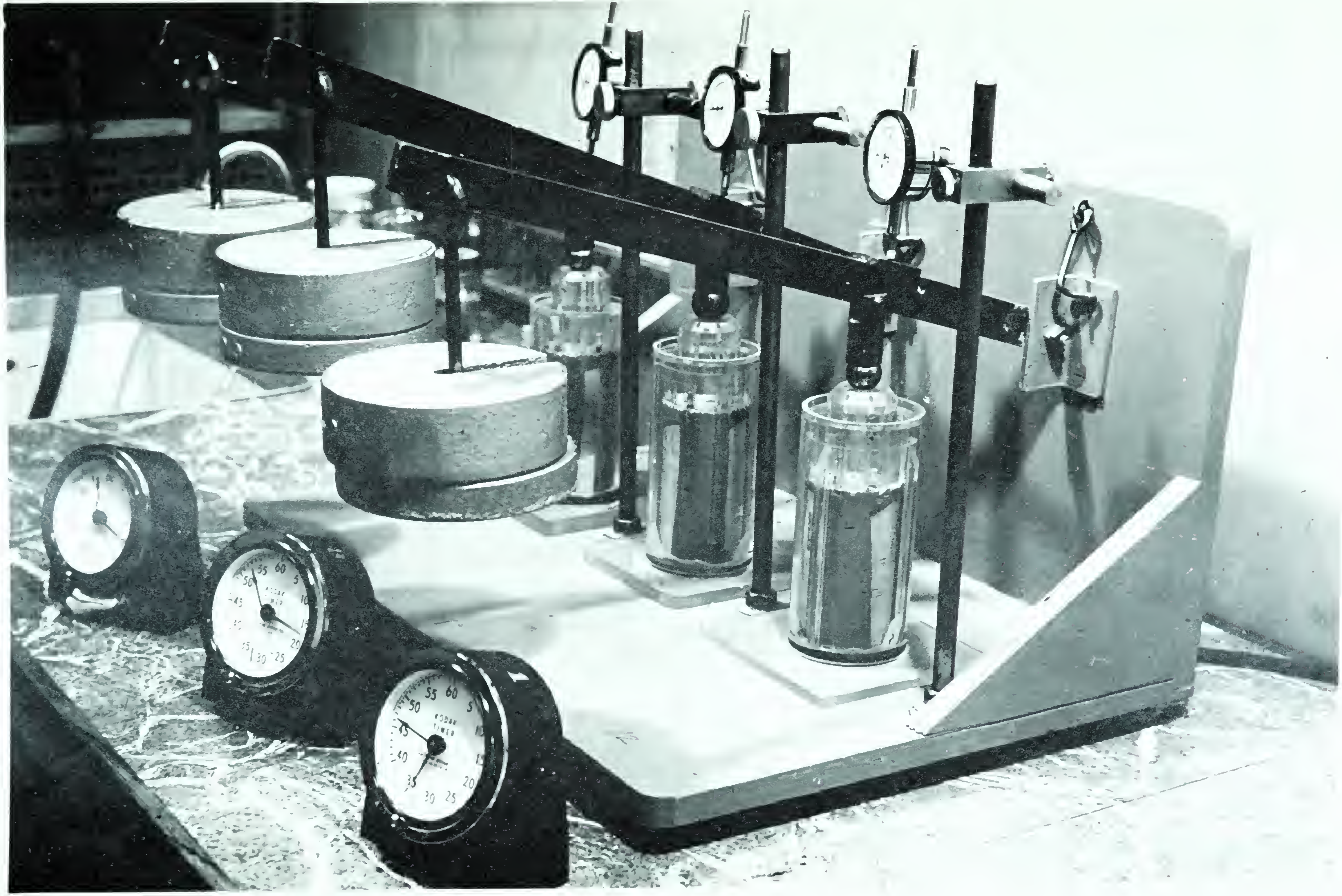


PLATE 4

APPARATUS FOR MOULDING THE TRIAXIAL TEST SPECIMEN

cylinder was rapped sharply against the counter top at frequent intervals to remove entrapped air. This procedure was carried on until the level of the soil was within ½ inch of the top of the cylinder. Another porous bronze disc was then placed on top of the soil and a loading head placed on top of this disc. This loading cap was perforated so that drainage of water from within the sample could take place.

This assembled unit was then placed into the larger cylinder and the annular space between the cylinders filled with distilled water taking care that the water completely covered the soil.

Axial load was then applied to the soil specimen by means of weights and a lever system. Two load increments were applied to the soil, the first resulting in an axial stress of about 0.4 kg/cm^2 and the second about 1 kg/cm^2.

The usual procedure was to mould three samples at a time, take initial readings of the extensometers (used to measure the consolidation), then simultaneously place the initial load on the pan of the lever system and start a stop clock. Dial readings were then taken at time increments such that each succeeding time was approximately double the previous one.

When the time from the beginning of load application reached about 10 minutes, consolidation of the second specimen was begun and the third specimen started as soon as the second had consolidated for about 10 minutes. A plot of dial reading

versus logarithm of time was kept up simultaneously with the notation of dial readings. When it was definitely established that the secondary compression branch had been reached the second load increment was placed on the pan and readings noted and recorded in exactly the same manner as described above.

When the secondary compression branch had been reached under the second load increment, the load was removed from the pan and the containers taken into the moist room. The samples were extruded, in the direction of load application, by gently applying pressure onto the loading cap. They were then wrapped in aluminum foil, labeled, waxed thoroughly, and stored in an air tight container in the moist room until needed.

Triaxial Compression Test

All triaxial testing in this investigation was done as follows:

1. The sealing wax and aluminum foil was removed from a specimen taken from storage in the high humidity room.
2. The specimen was then mounted in a trimmer and shaped by means of a wire saw, Plate 5. A moisture content determination was taken from the excess material removed.
3. The specimen was then placed in a trimming cradle and the ends planed off perpendicularly to its longitudinal axis. This procedure yielded a specimen 80 mm. in length with an approximate cross-sectional area of 10 cm^2.

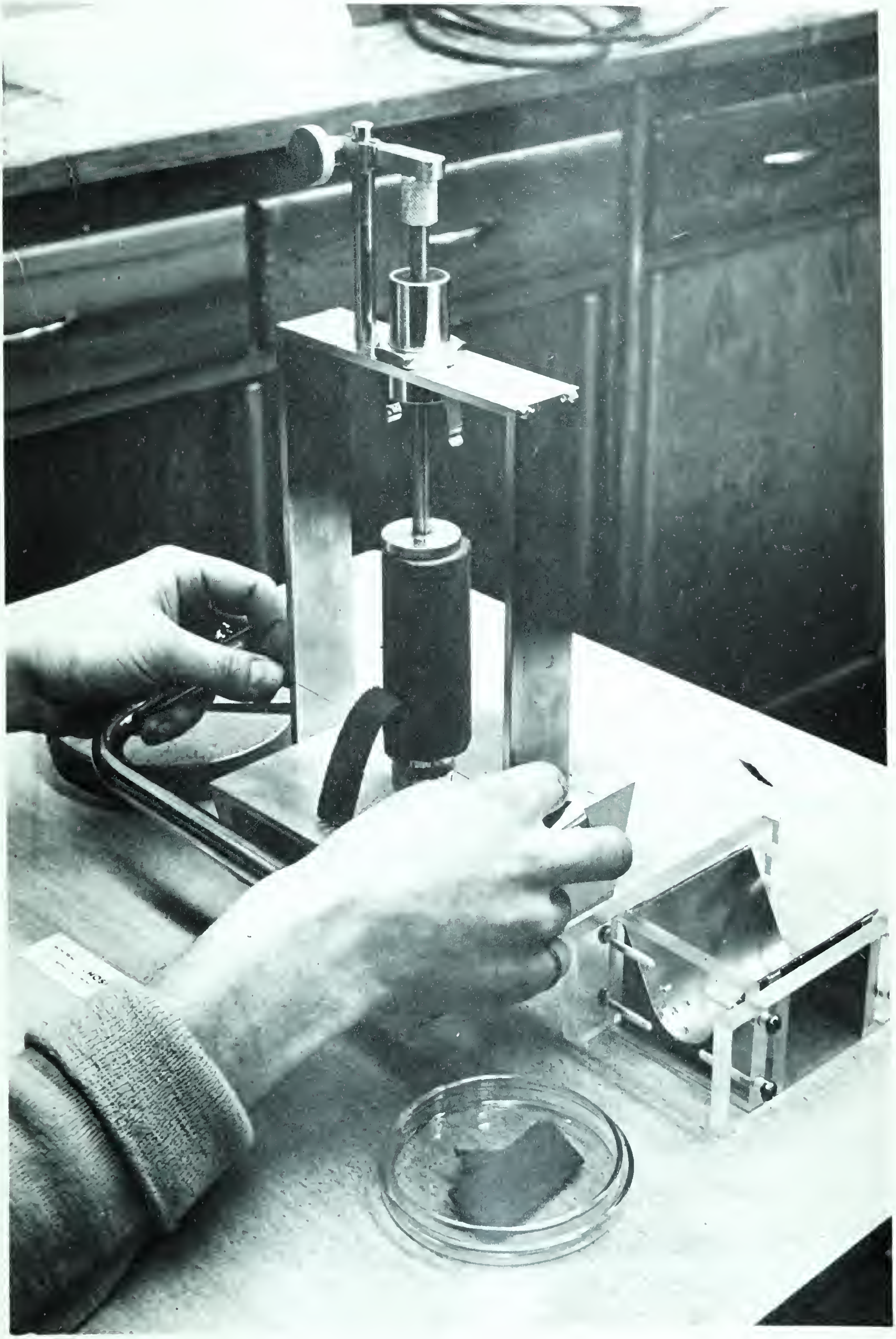


PLATE 5

TRIMMING THE TRIAXIAL TEST SPECIMEN

4. The specimen dimensions were then measured by means of calipers and recorded. The length was taken as the average of two measurements and the diameters at the top, centre, and bottom, were taken as the average of two measurements, each one at 90 degrees to the other. The initial cross-sectional area was computed as:

$$A_o = \tfrac{1}{4} (A_T + 2A_c + A_B)$$

where A_o is the initial cross-sectional area

A_T is the average area of the top

A_c is the average area of the centre

A_B is the average area of the bottom

5. The specimen was then replaced in the cradle and 5 saturated wool wicks were inserted into it. These wool wicks extended from the bottom of the specimen to within 1 cm of the top and were placed in a symmetrical pattern by means of a specially made template, Plate 5. The specimen was covered by means of aluminum foil during this process to minimize surface evaporation.

6. The sample was then weighed, covered in aluminum foil and placed in a high humidity container until needed.

7. A 25 cm^3 burette, graduated in 0.1 cm^3, with a stop-cock on its lower end, was then filled with distilled deaired water and placed in communication with one of the leads to the bottom pedestal of the triaxial cell. The stop-cock was opened and water was allowed to flush through the lines to expell any entrapped air. With the stop-cock still opened

the other line to the bottom pedestal was closed off by means of a tapered steel bung.

8. A saturated porous ceramic stone was then placed in contact with the bottom of the specimen and saturated filter strips wrapped around the outer periphery of the soil sample such that contact was made with these strips and the stone. The sample was then carefully placed on the pedestal.

9. The top loading head was then carefully centered onto the specimen, and a rubber membrane (Shiek protective) was placed around the specimen by means of a membrane stretcher. A thin layer of silicone grease (Dow Corning high vacuum grease) was carefully spread onto the membrane. A second membrane was then placed over the first followed by a second application of the above mentioned grease.

10. The membranes were then secured to the top loading cap and the bottom pedestal by means of two 'O' rings at each extremity.

11. The lucite chamber was then carefully lowered into place, securely clamped, and the cell filled with water to within 3/4" to 1" of the top plate.

12. Oil (Esso Teresso No. 65) was then poured through the piston opening to seal this void. (The purpose of this oil was to act as an air seal and as an insulation in this series of tests.)

13. The loading piston was then placed and allowed to just make contact with the top loading cap. A holding clamp was

swung into position over the piston and securely fastened.

14. By means of a screw control, linked with the cell just assembled, any free air was driven out through a valve on the top plate of the cell, after which this valve was shut.

15. The lines connecting the burette to the base of the specimen were then carefully flushed out by means of a gravity flow of water out of the burette. Water was allowed to flow through this portion of the system until no air bubbles could be detected after which the stop-cock on the burette was shut off.

16. An insulating disc was then placed beneath the cell and two vinyl insulating strips secured around the lower portion of the cell by means of wide rubber bands, Plate 2.

17. The required cell pressure was then slowly built up by means of an appropriate screw control and the constant pressure device put into communication with the cell.

18. Circulation of the cooling fluid was then begun; the fluid in the cooling tank having been previously conditioned to the required temperature.

19. The automatic temperature recorder was then started.

20. The flow control valves were then manipulated so that the temperature in all three triaxial cells was the same as close as could be achieved. (The usual procedure was to set up three triaxial cells at a time.)

21. When the temperature had reached a steady state condition for at least 3 hours, consolidation under the required confin-

ing pressure was begun. An initial burette reading and time was noted and recorded and the burette stop-cock opened simultaneously with starting of a stop clock. See Plate 6.

22. Burette readings, at frequent time intervals but including times such that each succeeding one was double the preceding one, were noted and recorded until it had been definitely established that the secondary compression branch had been reached. This was arrived at by means of a plot of burette readings versus logarithm of time which was kept up simultaneously with the notation of readings.

23. When consolidation was completed, the valve on the burette was closed off and the triaxial cell was placed on the loading press.

24. Water was flushed through the bottom lines once more by means of the burette.

25. With water flowing through one of the lines connected to the porous bottom disc, the pore pressure measuring device was placed in communication with this porous stone.

26. By means of the screw control interconnected with the pore pressure measuring device, water under a pressure not greater than about 0.2 kg/cm^2 was flushed through the bottom lines after which the burette was disconnected and the line shut off by means of a tapered steel bung.

27. An appropriate sized proving ring was then set into place, see Plate 2.

28. A back-pressure of 2.0 kg/cm^2 was then applied to the

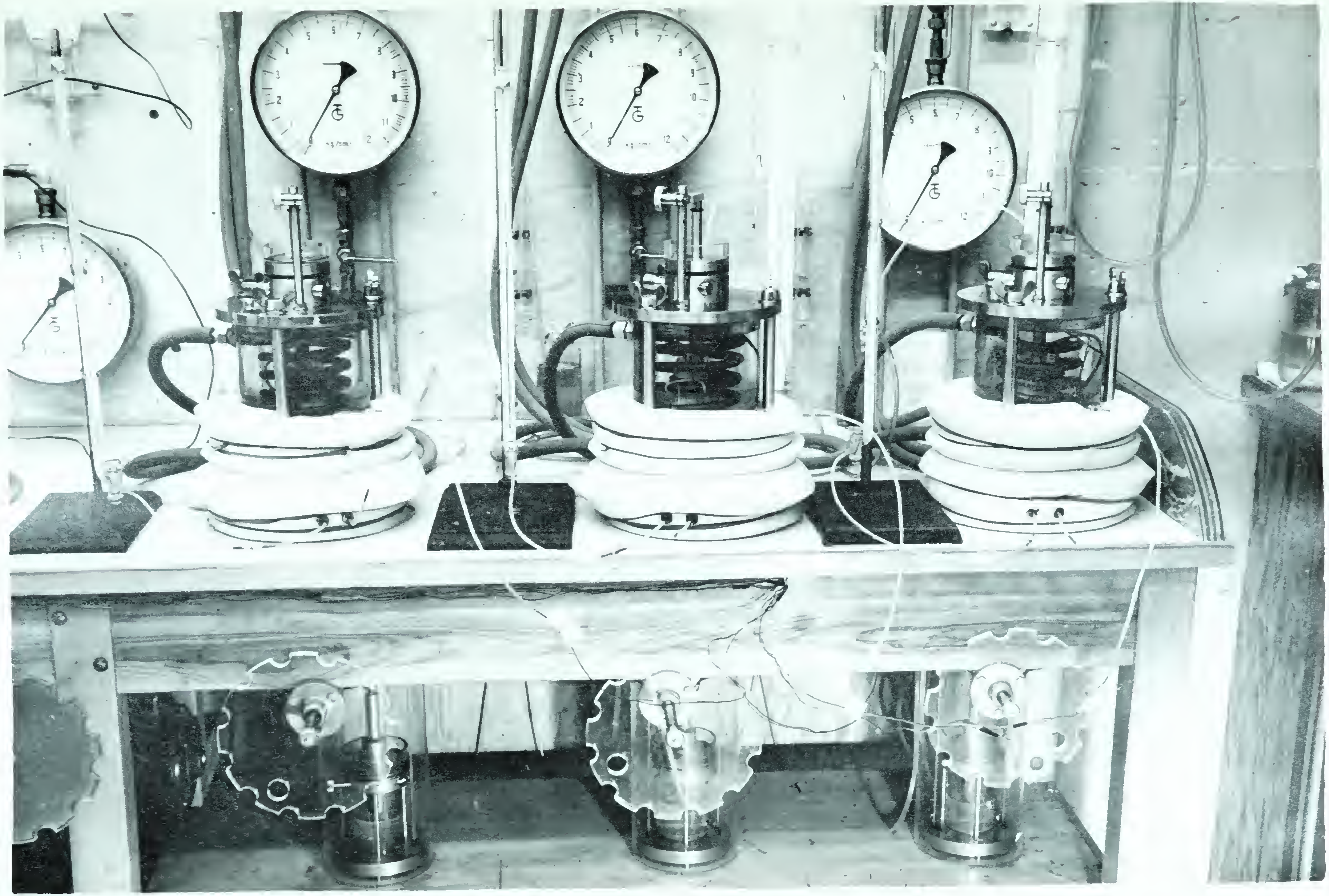


PLATE 6

TEST SERIES PRIOR TO CONSOLIDATION

specimen. This was accomplished by means of simultaneously and slowly increasing the cell pressure and the pressure within the specimen in increments of 0.1 kg/cm^2. The appropriate constant pressure devices were then put into play.

29. The by-pass valve, in the pore pressure device, was then shut and the triaxial cell allowed to sit over night. (This back-pressure procedure was in all cases applied on the evening prior to the test, for the sake of convenience.)

30. On the following morning a pore pressure reaction test was conducted. This was done by increasing the cell pressure by 1 kg/cm^2 simultaneously with starting a stop-clock and observing the induced pore pressure changes with time. After four or five minutes, this additional cell pressure was removed and the pore pressure change was again observed with time.

31. The bed of the loading press was then raised until the loading piston just made contact with the top loading cap. The stress and strain extensometers were adjusted and straining of the specimen was begun simultaneously with starting of a stop-clock.

32. Readings of time, stress and strain dials, (strain being based on the original length of the specimen), and pore pressure were made at increments of strain of 0.1% up to 2%, 0.25% up to 4% and 0.5% thereafter until failure had occurred.

33. By means of a desk calculator the deviator stress, major and minor principal effective stresses, effective principal

stress ratio, and $\bar{A}$ were computed as the test progressed. Plots of these quantities plus observed values of pore pressure versus per cent axial strain were maintained as the test progressed.

34. The sample was compressed until the axial strain was several per cent greater than that at the maximum effective principal stress ratio. The time required for completion of such a test on the average was about 8 hours.
35. At the completion of the test, the cell pressure and the back-pressure were removed taking extreme precaution not to alter the condition of moisture content within the specimen.
36. The base of the loading press was then lowered, the proving ring removed and the clamp positioned over the loading piston.
37. The cell was then dismantled and the specimen stripped of its enclosing membranes and filter strips, and immediately weighed.
38. A sketch was made of the mode of failure and the volume of the specimen was determined by means of mercury immersion.
39. The entire sample was then dried to constant weight in an oven at a temperature of 110°C, for a determination of final average moisture content.
40. From the data obtained, both from the initial and final conditions of the sample, void ratio and degree of saturation computations were made.

A complete set of data for a representative triaxial test will be found in Appendix 1.

Consolidation Tests

Preparation of the sample.

Samples for the one-dimensional consolidation tests were prepared in the following manner for both the soil types investigated.

1. About 100 grams of the air dried soil, reserved for this test, was thoroughly mixed with distilled water such that the moisture content would be as close as possible to the liquid limit.
2. This soil paste was then covered with a moistened paper towel followed by a second covering of aluminum foil, to prevent surface evaporation, and stored for a period of at least 48 hours in the temperature environment at which the test was to be run.
3. A piece of filter paper (Watman No. 54) slightly larger in diameter than a standard consolidation ring was then placed on a glass plate and the consolidation ring placed on top of it.
4. The soil was then again thoroughly mixed and then placed into the ring by means of a spatula in small portions, tamping and kneading it throughout this procedure to eliminate as much entrapped air as possible.
5. When the ring was filled the soil was struck off flush with the top of the ring and a second piece of filter paper, the same size as the inner diameter of the ring, was placed on the soil.

6. The initial weight of the soil plus ring was then determined and recorded after which it was transferred into the consolidation dish.

Consolidation procedure.

7. The weight of the top loading cap plus steel ball was then determined and recorded.

8. The tray containing the consolidating ring was then placed on the bed of the consolidometer. In addition an extensometer with the required fittings, and a container filled with distilled water was placed on the bed, and the machine was tared.

9. The upper loading cap was then placed onto the soil sample and the tray centered below the loading yoke.

10. The extensometer was adjusted such that it just made contact with the steel ball.

11. By means of a loading jack connected to a hand wheel, the bed was raised until the steel ball just made contact with the loading yoke. The apparatus was then allowed to seat itself for a few moments after which an initial dial reading was taken.

12. Distrilled water was poured into the tray such that the level of the water completely covered the consolidation ring.

13. A thermocouple was placed in this surrounding water and the automatic recorder started.

14. A 20 gm. load was placed on the pan and transmitted to the soil by means of the hand wheel until the lever arm was balanced.

15. When this balancing was done a stop watch was started and dial readings were taken at time increments of 6 sec, 15 sec, 30 sec, 1 min, 2 min, etc., with each successive time approximately double the preceding one.

16. After secondary compression had been reached, under the imposed load, another load increment was placed on the pan such that the total load was double the preceding one. The load was transmitted to the soil as in step 14 and dial readings taken as in step 15.

17. When the consolidation was complete, under the imposed load of 1.88 kg/cm^2, rebound was allowed to take place. This was accomplished by reducing the load on the pan to one quarter of its original value and the soil allowed to swell. Time and dial readings were again recorded as in step 15.

18. When the load on the pan reached its original value and rebound completed the process of re-loading as in steps 14 and 15 was again repeated, approximately doubling the preceding load increment, until the capacity of the consolidation machine was reached. (29.91 kg/cm^2)

19. Rebound was again carried out, starting from the last loading increment as in step 17, until the original load increment was reached.

20. When no more swelling could be observed, the extensometer was removed and the apparatus dismantled. Any excess water from the ring and the soil surface was carefully dried and the wet weight of the sample plus ring was determined and

recorded.

21. The ring and sample was then placed in a drying oven and the oven-dry weight determined and recorded. The weights of the filter paper were accounted for in each of the weighings.

CHAPTER V

RESULTS AND DISCUSSION

Record of Temperature for Triaxial Tests

Low temperature series

Table 2 is a typical record of temperatures for a set of two triaxial tests performed in the test cells while noting the temperature in the soil specimen and surrounding fluid in the third or reference cell. This table was constructed by listing the temperatures recorded on the strip chart, at thirty minute intervals, and determining the arithmetic mean. This time interval was chosen on the basis of convenience. (The recorder read out a temperature every 4 minutes.)

It soon became apparent that there was an increase in the cell temperature after the consolidation in the triaxial cell was completed and the cell mounted on the loading press. This was due to the fact that the cell now rested on the metallic base of the loading press whereas previously it sat on a wooden counter top, the latter condition providing additional insulation to the triaxial cell. Hence it became necessary to distinguish between the temperature at which the soil consolidated and that holding during the period of compression. This was felt necessary since any manipulation of the flow control valves would have resulted in large

irregularities of the test temperatures in the other cells.

Accordingly the temperatures, for the period of three-dimensional consolidation and the compression portion of the test, were summed and the arithmetic means, for the respective times, were determined. In addition the average temperature in the reference cell (both in the fluid and in the soil specimen) was determined for the corresponding time increments in the test cells. These average temperatures, for the first test series on the C H Edmonton clay at low temperature, are summarized in Table 3.

It can be seen that the average temperature in both the test cells and in the reference cell compare favourably but that there can exist a rather large range between a high and a low value in any given test. The worst condition observed during this series of tests was for the case of thermocouple No. 9 located in the soil in the reference cell for test No. 3-35, table 3. In this instance the highest reading recorded was 36.5°F and the lowest reading recorded was 32.5°F for a total interval of 4°F. Considering the series as a whole the maximum interval in the reference cell was 4.2°F in the fluid and 4.1°F in the soil specimen. In the test cells the largest spread in temperature during the periods of consolidation was 4.2°F and 3.2°F during the setting up and compression portion of the triaxial test.

Even though this variation in temperature is undesirable it was felt that because of the comparatively

TABLE 2

TYPICAL RECORD OF TEMPERATURE FOR TRIAXIAL TEST USING REFERENCE CELL

(Test No. 4-35 and 5-35)

Date and Time	*Temperature for thermocouple No.					Remarks
	2	9	6	14	16	
24/1/62						
15:30	35.5	37.4	35.8	35.8	33.8	Begin consolidation test No. 5-35
16	35.5	37.4	35.8	35.8	33.7	
30	35.4	37.2	35.8	35.8	33.9	Begin consolidation test No. 4-35
17	35.6	37.3	36.0	36.0	33.9	
30	35.5	37.3	36.0	36.0	33.9	
18	35.5	37.3	36.0	36.0	34.0	
30	35.5	37.3	36.0	36.0	33.9	
19	35.3	37.2	35.8	35.8	33.8	
30	35.3	37.2	35.8	35.8	33.6	
20	35.5	37.2	36.0	36.0	33.9	
30	35.2	37.0	35.7	35.7	33.9	
21	35.2	37.2	35.7	35.7	33.1	
30	35.0	36.7	35.5	35.5	32.7	
22	35.2	36.7	35.6	35.6	33.9	
30	35.3	37.1	35.8	35.8	33.9	
23	35.4	37.0	35.8	35.8	33.6	
30	35.0	37.0	35.5	35.5	33.0	
24	35.3	37.0	35.7	35.7	33.7	
30	35.3	37.0	35.8	35.8	33.4	
25/1/62						
1	35.0	36.5	35.5	35.5	33.5	
30	35.0	36.5	35.5	35.5	33.7	
2	35.3	37.0	35.7	35.7	33.7	
30	35.3	37.0	35.7	35.7	33.8	
3	35.2	36.9	35.5	35.5	33.2	
30	35.2	36.8	35.6	35.6	33.5	
4	35.3	36.8	35.6	35.6	33.7	
30	35.3	36.8	35.6	35.6	33.7	
5	35.0	36.7	35.5	35.5	33.7	
30	35.2	36.8	35.6	35.6	33.7	
6	35.1	37.0	35.6	35.6	33.6	
30	35.0	36.4	35.4	35.4	33.8	
7	35.3	36.6	35.6	35.6	33.9	
30	35.1	36.9	35.6	35.6	33.5	
8	35.1	36.9	35.6	35.6	33.9	
30	35.2	36.9	35.6	35.6	33.9	
9	35.4	37.0	35.7	35.7	34.0	
30	35.1	36.8	35.5	35.5	33.1	

TABLE 2 (Continued)

Date and Time	*Temperature for thermocouple No.					Remarks
	2	9	6	14	16	
10	35.1	36.9	35.6	35.6	33.5	
30	35.1	36.9	35.6	35.6	33.5	
11	35.1	36.5	35.0	35.0	32.5	
30	35.1	36.4	35.5	35.5	33.7	
12	35.3	36.8	35.7	35.7	33.9	
30	35.3	37.0	35.7	35.7	33.8	
13	35.4	37.0	35.8	35.8	33.7	
30	35.3	37.0	35.8	35.8	33.7	
14	35.4	37.0	35.8	35.8	33.7	
30	35.1	37.0	35.6	35.6	32.6	
15	34.9	36.4	35.1	35.1	33.5	
30	35.2	37.0	35.6	35.6	33.5	
16	35.3	37.0	35.8	35.8	33.9	
30	35.3	37.0	35.8	35.8	33.5	
17	35.1	37.0	35.6	35.6	33.0	
30	35.3	37.0	35.9	35.9	33.9	
18	35.4	37.0	35.8	35.8	33.6	
30	35.4	37.0	35.9	35.9	33.7	
19	35.3	37.0	35.7	35.7	33.8	
30	35.4	37.0	35.8	35.8	33.9	
20	35.0	36.6	35.5	35.5	33.5	End consolidation test No. 5-35 T.C. No. 6
30	35.1	36.6	35.7	35.5	33.5	
21	35.4	36.9	36.0	35.7	33.7	
30	35.2	37.0	36.0	35.7	33.5	
22	35.3	37.0	36.0	35.8	33.8	
30	35.2	37.0	36.0	35.7	33.8	
23	35.3	37.0	36.0	35.7	33.4	
30	35.4	37.0	36.0	35.7	33.9	
24	35.3	37.0	36.0	35.8	33.9	
30	35.4	37.0	36.0	35.3	33.7	
26/1/62						
1	35.3	37.1	36.0	35.7	33.9	
30	35.2	37.0	35.8	35.6	34.0	
2	35.3	37.0	36.0	35.7	33.9	
30	35.3	37.1	36.0	35.7	33.0	
3	35.2	37.0	36.0	35.7	33.8	
30	35.5	37.0	36.0	35.7	34.0	
4	35.0	36.8	35.7	35.5	33.5	
30	35.3	37.0	36.0	35.8	33.9	
5	35.2	37.0	36.0	35.7	33.5	
30	35.3	37.0	36.0	35.7	33.9	
6	35.4	37.0	36.0	35.9	34.0	
30	35.5	37.2	36.0	36.0	34.0	
7	35.2	37.0	36.0	35.7	33.6	
30	35.4	37.0	36.0	35.8	33.9	

TABLE 2 (Continued)

Date and Time		*Temperature for thermocouple No.				Remarks
		2	9	6	14	16	
8		35.4	37.0	36.0	35.8	33.7	
	30	35.3	37.0	36.0	35.8	33.5	
9		34.9	36.5	35.5	35.2	33.3	
	30	35.4	36.9	36.0	35.8	33.5	
10		35.1	36.6	35.8	35.6	33.8	
	30	35.3	37.0	36.0	36.0	34.0	
11		35.6	37.1	36.1	36.0	33.6	
	30	35.2	37.0	35.9	35.8	33.6	
12		34.4	36.7	34.9	35.0	31.7	
	30	35.0	36.3	35.2	35.2	33.1	
13		35.5	36.8	35.6	35.8	33.8	
	30	35.5	37.2	36.0	36.0	33.9	
14		35.5	37.2	36.0	36.0	34.0	
	30	35.5	37.3	36.1	36.1	33.6	
15		35.5	37.4	36.1	36.0	33.7	
	30	35.3	37.2	36.0	36.0	33.7	
16		35.5	37.2	36.0	36.0	33.8	
	30	35.4	37.3	36.6	36.0	33.7	
17		35.0	37.0	36.0	35.5	33.5	
	30	35.3	37.2	36.5	35.8	33.6	
18		35.5	37.2	36.6	36.0	33.8	
	30	35.3	37.3	36.6	35.8	33.3	End triaxial test No. 5-35 T.C. No. 6
19		35.1	37.0	36.4	35.7	33.5	
	30	35.3	37.1	36.5	35.8	33.8	
20		35.4	37.1	36.6	36.0	33.3	End consolidation test No. 4-35
	30	35.4	37.1	36.3	36.0	33.8	
21		35.5	37.2	36.2	36.5	33.7	
	30	35.2	37.1	36.0	36.6	32.9	
22		35.3	37.0	36.0	36.8	33.9	
	30	35.4	37.1	36.0	36.8	33.9	
23		35.3	37.1	36.2	37.0	33.8	
	30	35.4	37.4	36.7	36.7	33.7	
24		35.1	36.8	35.9	36.5	33.8	
	30	35.1	37.0	35.9	36.5	33.5	
27/1/62							
1		35.4	37.0	36.0	36.5	33.5	
	30	35.3	37.0	35.8	36.5	33.2	
2		35.3	37.0	36.0	36.5	33.5	
	30	35.1	36.8	35.7	36.3	33.6	
3		35.5	37.0	36.0	36.6	33.9	
	30	35.4	37.0	36.0	36.5	34.0	
4		35.5	37.0	36.0	36.5	33.9	
	30	35.2	36.7	35.7	36.0		
5		35.2	37.0	35.9	36.2	33.7	
	30	35.1	37.0	35.7	36.0	33.7	

TABLE 2 (Continued)

Date and Time		*Temperature for thermocouple No. 2	9	6	14	16	Remarks
6		35.4	37.0	36.0	36.2	33.4	
	30	35.5	37.0	36.1	36.1	34.0	
7		35.4	37.0	36.0	36.4	33.0	
	30	35.5	37.0	36.0	36.4	33.8	
8		35.5	37.0	36.1	36.6	33.8	
	30	34.0	35.6	34.4	34.7	32.0	
9		35.0	36.0	35.3	35.6	34.0	
	30	35.1	36.7	35.6	36.0	33.3	
10		35.3	36.8	36.0	36.3	34.0	
	30	35.6	37.1	36.1	36.6	33.8	
11		35.5	37.2	36.1	36.7	33.9	
	30	35.5	37.2	36.1	36.7	34.0	
12		35.6	37.3	36.1	36.7	33.8	
	30	35.7	37.3	36.2	36.8	33.9	
13		35.5	37.2	36.0	36.6	34.0	
	30	35.0	37.0	35.6	36.1	32.6	
14		35.4	36.9	36.0	36.3	33.5	
	30	35.5	37.1	36.0	36.8	33.7	
15		35.5	37.2	36.0	36.8	33.9	
	30	35.4	37.0	36.0	36.8	33.6	
16		35.5	37.0	36.0	36.8	33.7	
	30	35.5	37.0	36.0	36.8	33.5	
17		35.6	37.4	36.2	36.8	33.8	
	30	35.5	37.5	36.2	36.8	33.8	
18		35.3	37.4	36.1	36.5	33.3	
	30	35.6	37.3	36.0	36.6	33.6	
19		35.5	37.4	36.0	36.5	33.7	
	30	35.6	37.5	36.3	36.6	33.7	
20		35.7	37.5	36.2	36.5	33.8	
	30	35.7	37.5	36.3	36.4	33.5	
21		35.2	37.4	36.0	36.0	33.0	End triaxial test No. 4-35

*Thermocouple No. 2 in reference cell.
Thermocouple No. 9 in soil in reference cell.
Thermocouple No. 6 in cell test No. 5-35.
Thermocouple No. 14 in cell test No. 4-35.
Thermocouple No. 16 in cold tank.

Note:

All temperatures in degrees Fahrenheit.
Thermocouple correction has not been applied.

TABLE 3

SUMMARY OF TEMPERATURES IN REFERENCE
AND TEST CELLS ON C H EDMONTON CLAY

Test No.	Confin. Press. (Kg/cm^2)	Reference Cell		Difference T.C.9-T.C.2 (^{o}F)	T.C.	Test Cells	
		T.C.2 (^{o}F)	T.C.9 (^{o}F)			Consolidate (^{o}F)	Setup & Break (^{o}F)
1-35	1.5	(34.8) 34.2 (32.2)	(36.4) 36.0 (34.0)	1.8	6	(35.4) 34.9 (33.0)	(35.7) 35.1 (33.7)
2-35	2.25	(34.2) 34.1 (30.6)	(36.2) 35.8 (32.5)	1.7	6	(35.0) 34.5 (31.2)	(35.7) 35.4 (34.3)
3-35	4.0	(34.7) 34.2 (32.7)	(36.5) 35.9 (32.5)	1.7	14	(35.2) 34.7 (31.8)	(36.0) 35.2 (34.2)
4-35	5.5	(34.7) 34.4 (33.6)	(36.6) 36.2 (35.6)	1.8	14	(35.2) 34.9 (34.4)	(36.2) 35.7 (34.8)
4-35* repeat	5.5	(34.5) 34.2 (33.5)	(36.4) 36.0 (35.4)	1.8	6	(35.2) 35.0 (34.1)	(35.7) 35.2 (33.0)
5-35	6.25	(34.7) 34.3 (33.6)	(36.6) 36.2 (35.6)	1.9	6	(35.2) 34.9 (34.2)	(35.3) 35.2 (34.4)

Note:

Figures in brackets above and below average temperature are the high and low temperature respectively for that test.

*The results of this test have not been used in the analysis of strength.

Abbreviations:

Confin. = Confining

Press. = Pressure

T.C. = Thermocouple

large range in the two temperature extremes desired to be investigated, (approximately 40°F) that this spread would be tolerable.

On the basis of differences in average temperatures between the surrounding fluid and the soil, column 5 of Table 3, it can be seen that the temperature in the central portion of the test specimen is very nearly 1.8°F higher than the ambient fluid temperature at the corresponding level. Thus the average temperature within the specimen, in the low temperature range investigated, was assumed to be 1.8°F higher than the ambient fluid temperature as measured by thermocouples in the test cells. This correction has been applied to all average temperatures presented in subsequent results unless otherwise noted.

Following this initial series of triaxial tests the top loading cap and its accompanying thermocouple was then removed from the reference cell and the cell put into service to hasten the testing programme.

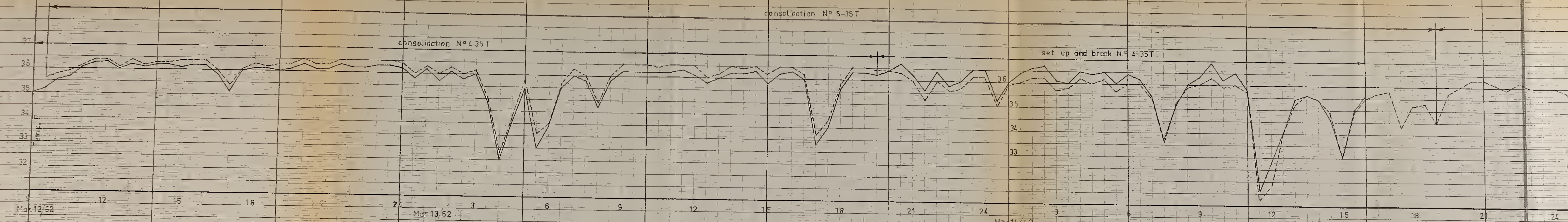
A complete record of temperatures holding within the triaxial cells will be found in Tables 16 to 36 of Appendix II. The strip charts from which these tables were obtained are on file with the Department of Civil Engineering under separate cover. The average temperature in the soil specimen together with the high and low values recorded in each triaxial test are summarized in Tables 4 and 10 together with other triaxial test data, for the low temperature series

on both soil types.

From Table 4 it can be seen that for the period of 'set up and break', i.e. setting the triaxial cell on the loading press and compressing it to failure, the temperatures, expressed as an average over this time increment, compared with each other favourably. The highest and lowest values recorded were 37.5°F and 35.9°F respectively. The range in temperature between the high and low value for an individual test was greatest for test No. 4-35 (rep.), which was 2.1°F.

For the low temperature series on the Edmonton till, Table 10, it can be seen that the range between maximum and minimum temperatures in any given test was much greater than for the corresponding series on the C H Edmonton clay. Even so there is only a difference in the average values of 1.0°F. The largest difference in a given test occurred on the last triaxial test performed. This was test No. 5-35 T, in which case the increment was found to be 5.9°F. The range between the highest and lowest values, on the basis of the whole test series, was 6.6°F, which was the largest variation in the whole testing programme for the period of set up and compression. These much larger inconsistencies in temperatures were shown up in the late stages of the testing programme as is indicated by the results of tests 3-35 T, 4-35 T, and 5-35 T of Table 10.

Figure 2 (a) and (b) is a visual representation of the temperature variation with time. Figure 2 (b) represents



consolidation N° 5-35T
consolidation N° 4-35T
set up and break N° 4-35T
Temp. F
37
36
35
34
33
32
36
35
34
33
9
12
15
18
21
24
3
6
9
12
15
18
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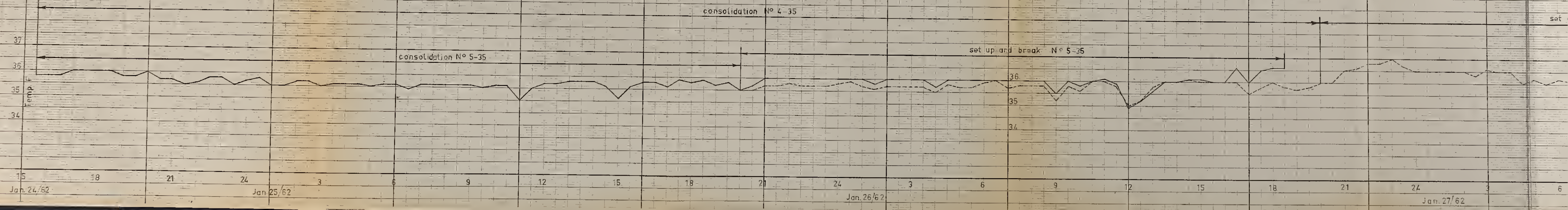

consolidation N° 4-35
consolidation N° 5-35
set up and break N° 5-35
set
Temp. F
37
36
35
34
36
35
34
15
18
21
24
3
6
9
12
15
18
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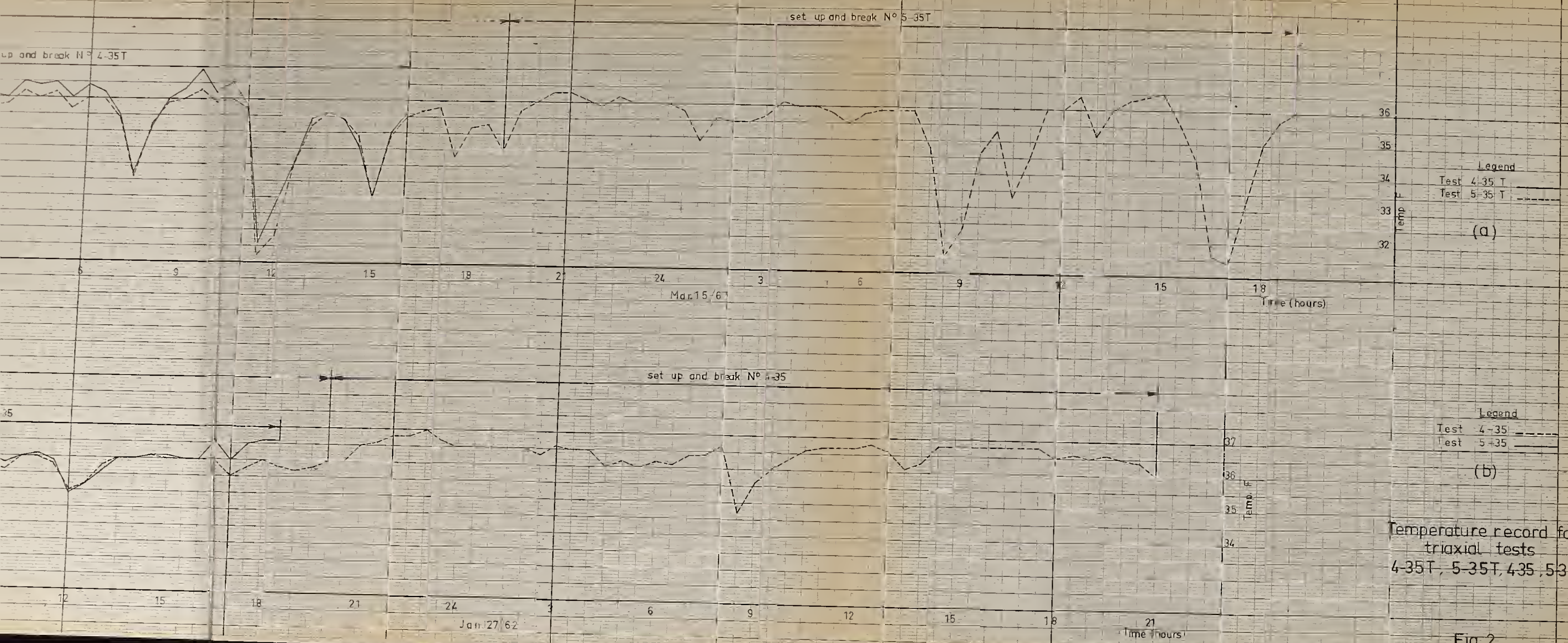
Jan. 25/62
Jan. 26/62
Jan. 27/62



Temperature record for
triaxial tests
4-35T, 5-35T, 4-35, 5-35

Fig. 2

the results of the early testing whereas Figure 2 (a) represents the results of the last triaxial tests run in the low temperature series. It is evident that the temperature control system deteriorated to a marked degree as the testing progressed. It is believed that the bimetallic thermoswitch was the source of the trouble and would not open cleanly at the desired low temperature, this condition becoming worse with continued use.

High temperature series.

Previous experience with temperature measurement in a consolidation test at room temperature disclosed that over a period of one month the largest difference between a high and low value was 5.2°F, see Table 7. These temperatures were measured in the water surrounding the consolidating specimen by means of thermocouples and recorded on strip charts. This range in temperature is comparable to that determined from the preliminary triaxial test series at the low temperature. Hence it was decided to run the second series of triaxial tests at room temperature and thus secure additional useful data as to the actual changes in temperature which do take place within a triaxial cell.

The results of the tests on both soil types at the room temperature (high temperature range) will be found in Appendix II. A summary of the average, high and low temperatures recorded are summarized in Tables 5 and 11. The strip charts supporting these data are on file with the Department

of Civil Engineering under separate cover.

For the series on the C H Edmonton clay for the period of 'set-up and break' the spread in temperature between the lowest and highest values was found to be 4.9°F. Correspondingly this was found to be 4.3°F for the test series on the Edmonton till.

The same precaution was taken to insulate the triaxial cells in these series of tests, as was done for the series at low temperature. Hence it can be concluded that with a moderate amount of insulation, the variation in temperature within the central portion of a triaxial cell is relatively small. This observation applies to the laboratory in which the Geonor triaxial testing equipment is presently located.

General Considerations of the Triaxial Testing Programme

Specimen preparation.

The requirements for this investigation necessitated specimens which would be as identical as possible in initial void ratio, moisture content, particle orientation, mineralogical composition, and pore water. Such duplication could only be hoped for in remoulded samples.

Accordingly the specimens were prepared from the minus No. 40 sieve size fraction of each soil type from the air dry state. The entire sample, reserved for a triaxial

test series, was thoroughly mixed before the samples were prepared in an effort to ensure uniformity in mineralogical composition. Distilled moulding water was used to ensure uniformity of concentration of soluble salts in the pore water, and the same technique was employed throughout in forming the specimens to ensure uniformity in particle orientation. All specimens were moulded from the liquid limit, as close as could be practicably obtained. The applied vertical stress in moulding the specimens was lower than the smallest confining pressure used in the triaxial tests and hence the samples were considered to be essentially normally consolidated.

One useful check on the initial conditions of the test specimens was made in each triaxial test sample. When the test specimen was being trimmed to its required dimensions, a moisture content determination was made from the excess material. The results of these determinations are listed in Tables 4 and 5 for the C H Edmonton clay and 10 and 11 for the Edmonton till. For the highly plastic clay the initial moisture content varied from a low value of 50.04% to a high value of 52.08%. In the case of the Edmonton till the spread was greater, varying from a low value of 24.05% to a high value of 27.02%. Compared with initial conditions which could exist in undisturbed samples obtained from the field, these initial moisture contents indicate good uniformity between specimens. However, the differences are far in excess

of experimental error in their determination suggesting that the technique of forming the specimens could be improved.

It is noted that in each instance the initial moisture content as determined from the initial wet weight of the specimen, is slightly greater than that determined from the trimmings. This is accounted for by the fact that additional water was introduced into the specimen by means of the 5 saturated internal wool drains and that the initial wet weight included this excess water.

Failure criteria.

According to Bjerrum and Simons (6) for undrained tests on normally consolidated clays two cases may arise. The pore pressure, at the point of maximum deviator stress, either reaches a maximum and the strain at maximum principal effective stress ratio coincides with that for the maximum deviator stress, or it continues to increase with additional strain. If the deviator stress remains constant or decreases slightly at strains beyond that for its maximum value, then the maximum effective principal stress ratio occurs at a larger strain than that for maximum deviator stress. The angle of shearing resistance can be appreciably greater for this condition. For remoulded material, the points of maximum deviator stress and maximum principal effective stress ratio are nearly coincident. This was the condition found in nearly all of the tests performed in this investigation.

There need be no immediate concern as to the failure criterion used in this series of triaxial tests provided that the same one is used in each instance. The maximum principal effective stress ratio was the one adopted in this investigation and all Mohr circles have been obtained on this basis.

Use of internal drains.

Five saturated wool drainage wicks were inserted into each specimen to within about 1 cm. from the top of the sample. These wicks were placed in contact with the porous drainage stone connected with the pore pressure measuring device. The reason for using this technique was to allow for a more equitable distribution of pore pressures within the specimen during the shearing portion of the triaxial tests, Schmertmann and Ostenberg (37). It must be conceded that additional disturbance is imparted to the specimen during this procedure but since these drains were placed by means of a template (see Plate 5), thus ensuring the same disposition in each sample, then the disturbance is the same in each instance.

Rate of strain used.

It is well recognized that variable rates of strain in undrained triaxial tests can have a marked effect on the induced pore pressure, Whitman (43). Therefore, to avoid any complications because of this variable, in this investigation a strain rate of 2.25% per hour was used throughout the entire

triaxial testing programme. This rate of axial strain was arbitrarily selected and allowed the compression portion of the triaxial test to be completed in from 6 to 8 hours.

Back pressure.

A back pressure of 2 kg/cm^2 was used in all the triaxial tests run in this investigation. Back pressuring increases the degree of saturation of the specimen and aids in the dissolving of air in the pore pressure measuring device thereby enhancing the reliability of the measured pore pressure. The back pressure was initiated on the evening prior to compressing the specimen, that is some 12 to 15 hours prior to the triaxial compression test. It was accomplished by increasing the pore pressure simultaneously with the cell pressure very slowly and in increments of 0.1 kg/cm^2 until the value of 2.0 kg/cm^2 was reached.

Inspection of Tables 4, 5, 10 and 11, discloses that the degree of saturation computed from the specimen dimensions varied with 2 exceptions from about 95% to 97%. Experimental error in determination of the degree of saturation was found to be in the order of ±1%, so that the deviations noted above are within the inherrent error in measurement. It is believed however, that the computed values of saturation are too low and reflecting back on the method used for final specimen volume determination reveals that such was the case. In each volume determination there was a systematic error involved which resulted in a final

measured volume which is too high. A method of immersion in mercury was used in determining the final volume of the failed specimen. It was found that in each instance there was too much mercury being displaced by an amount equal to 0.35 cm^3 when the specimen was immersed. Air can also be entrapped in this method of volume determination and it is not unreasonable to assume that the measured amount of mercury displaced could approach 0.5 cm^3. A computation was carried out on this basis and it was determined that the degree of saturation was raised some 1.5%.

The above arguments are of academic importance only and since it is not possible to determine the amount of air which can be entrapped, when immersion of the specimen is made, no correction to the degree of saturation was applied. The point is that the specimens approached complete saturation.

Pore pressure reaction tests.

Following the period of back pressure and immediately preceding the compression portion of the triaxial test a pore pressure reaction test was run on every sample. The response of the pore pressure measuring system was checked by increasing the chamber pressure without allowing the sample to drain, and observing the pore pressure response.

Table 14 of Appendix I is a summary of the results of reaction tests at a time of 2 minutes after the application of an additional 1 kg/cm^2 to the chamber pressure. With

the exception of 3 tests the reaction was found to vary from 70% to over 90% indicating an approach to complete saturation in the specimens. The presence of air is indicated in the 3 tests mentioned above. It is probably in the pore pressure measuring device, since there is no correlation between these tests and a correspondingly low computed value for the degree of saturation. There is no apparent trend evident to indicate anything which could be charged to the effect of temperature variation.

Results Obtained with C H Edmonton Clay

Triaxial compression tests.

Table 4 is a summary of the triaxial compression test results performed on the C H Edmonton clay at the low temperature and Table 5 is a summary of the test results performed at the high temperature. From these results the Mohr circles shown on Figures 3 and 4 were plotted. Figure 3 shows the Mohr circles obtained from the test series at the low temperature and Figure 4 for the series run at the high temperature, both in terms of total and effective stress. Figure 5 is a superposition of Figure 3 upon Figure 4 for ready comparison.

All failure envelopes were fitted by a method of least squares to eliminate any personal bias which may have arisen had the rupture envelope been drawn in by means of visual inspection.

Values of cohesion and angle of shearing resistance in terms of both total and effective stresses are summarized in Table 6 (a). In addition, the results of the above two tests have been combined and shown thereon.

The rupture envelopes for both total and effective stresses are well defined for the test series at the high temperature, Figure 4. Deviations from the computed rupture envelope are much more pronounced for the test series at the low temperature, Figure 3, particularly so for the effective stress rupture envelope. Since a better fit is obtained in terms of total stress then this must be explained in terms of improper measurement of induced pore pressure. This is because the deviator stress remains the same in terms of total or effective stress and the effective stress plot is simply a shifting of the Mohr circles of the total stress plot by an amount equal to the pore pressure.

It could be argued that the rather large variations in temperature, at the low end of the range being investigated, is the cause of the scatter evident in Figure 3. However, examination of temperature variation discloses that there is a greater spread in the series at the high temperature (4.9°F) than in the low temperature series (2.5°F). Hence, if temperature alone was responsible for scatter in the rupture envelope, then it should be more evident in Figure 4 than in Figure 3. The opposite is found to be the case.

The computed values for the shear strength

TABLE 4

SUMMARY OF TRIAXIAL COMPRESSION TESTS ON REMOULDED C H EDMONTON CLAY AT LOW TEMPERATURE

Test No.	σ_c kg/cm^2	W_i From Trim.	W_i Calc.	W_f	e_f	S_f	σ'_{1f} kg/cm^2	σ'_{3f} kg/cm^2	$\sigma_1 - \sigma_3$ kg/cm^2	P_p kg/cm^2	μ %	$\bar{A}$ %	Temperature* °F Consol.	Temperature* °F Comp.
1-35	1.5	50.08	51.50	43.54	1.31	93.5	1.57	0.52	1.05	0.98	11.5	93.3	(37.2) 36.7 (34.8)	(37.5) 36.9 (35.5)
2-35	2.25	51.46	52.46	40.95	1.19	96.5	2.52	0.98	1.54	1.27	9.5	82.5	(36.8) 36.3 (33.0)	(37.5) 37.2 (36.1)
3-35	4.0	50.04	51.33	36.92	1.06	97.4	4.30	1.82	2.48	2.18	9.5	87.9	(37.0) 36.5 (33.6)	(37.8) 37.0 (36.0)
4-35	5.5	50.44	51.92	33.78	0.99	96.0	6.25	2.53	3.72	2.97	10.5	79.8	(37.0) 36.7 (36.2)	(38.0) 37.5 (36.0)
4-35 (rep.)	5.5	51.89	53.21	34.72	1.02	95.2	6.07	2.39	3.68	3.11	13	84.5	(37.2) 35.9 (30.5)	(36.4) 35.9 (34.3)
5-35	6.25	49.37	51.33	33.57	0.97	97.4	6.93	2.91	4.02	3.34	11	83.1	(37.0) 36.7 (36.0)	(37.1) 37.0 (36.2)

Abbreviations:

Trim. = trimmings
Calc. = calculated from final condition
Consol. = period of triaxial consolidation
Comp. = period of triaxial compression

*Average temperature in the soil specimen. Figures in brackets above and below average value are the high and low value of temperature respectively.

TABLE 5

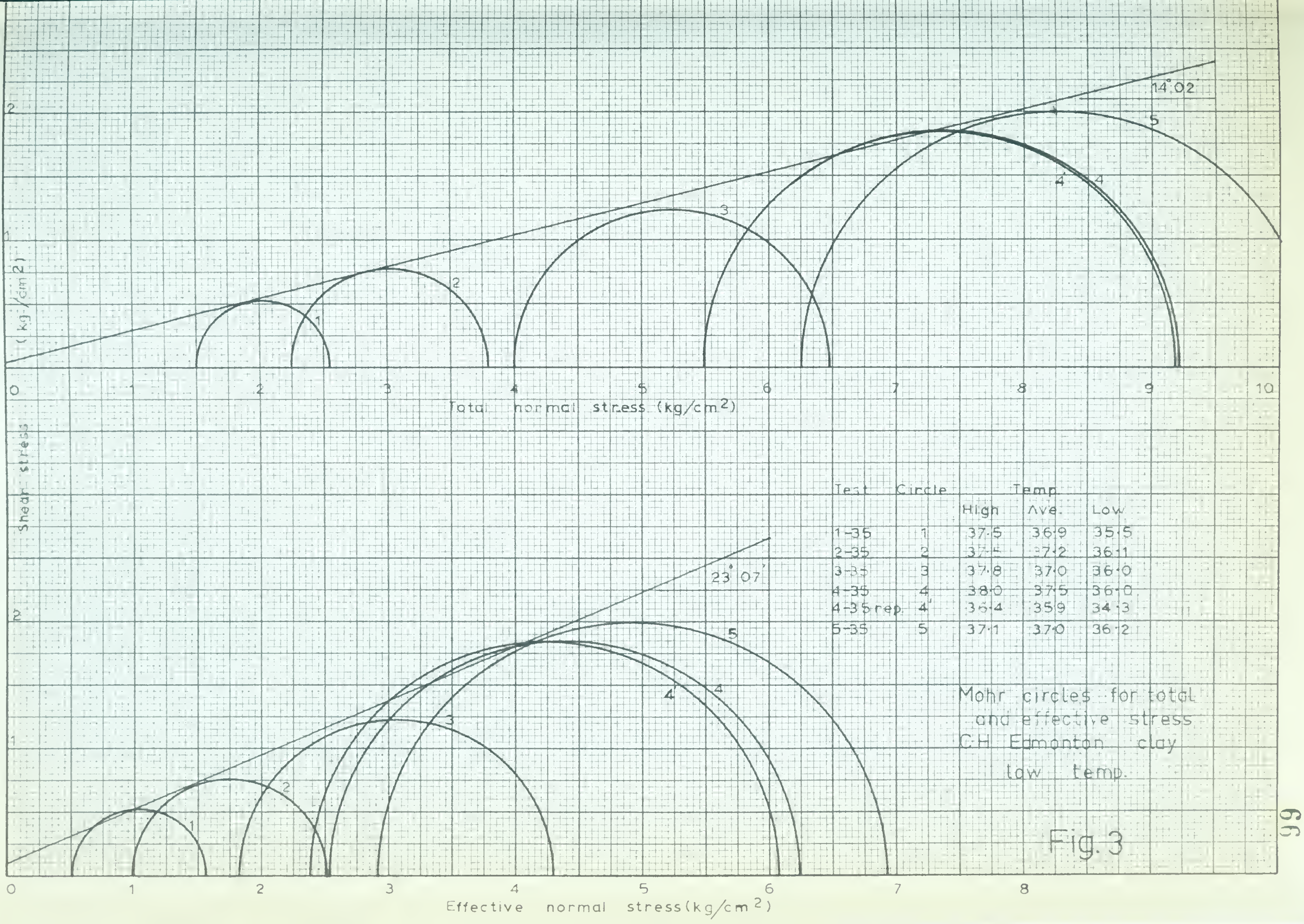
SUMMARY OF TRIAXIAL COMPRESSION TESTS ON REMOULDED C H EDMONTON CLAY AT HIGH TEMPERATURE

Test No.	σ_c kg/cm^2	W_i		W_f	e_f	S_f	σ'_{1f} kg/cm^2	σ'_{3f} kg/cm^2	$\sigma_1-\sigma_3$ kg/cm^2	P_p kg/cm^2	μ %	$\bar{A}$ %	Temperature* ^oF	
		From Trim.	Calc.										Consol.	Comp.
1-75	1.5	51.66	52.50	43.13	1.27	96.1	1.61	0.48	1.13	1.02	11.5	90.3	(80.8) 78.7 (77.8)	(80.7) 78.8 (77.8)
2-75	2.25	51.06	53.04	39.77	1.18	94.6	2.56	0.96	1.60	1.29	12.5	80.6	(79.8) 79.1 (78.1)	(79.2) 77.5 (76.5)
3-75	4.0	50.69	52.87	36.51	1.06	96.4	4.49	1.74	2.75	2.26	13.5	82.2	(76.7) 76.3 (75.7)	(79.3) 77.2 (76.2)
4-75	5.5	52.08	53.00	34.22	1.00	95.9	5.96	2.37	3.59	3.13	13.0	87.2	(78.2) 76.9 (76.3)	(79.2) 78.1 (76.7)
5-75	6.25	51.46	52.61	33.13	0.97	95.3	6.71	2.67	4.04	3.58	15.0	88.6	(79.1) 77.7 (76.5)	(79.1) 76.0 (75.8)

Abbreviations:

Trim. = trimmings
Calc. = calculated from final condition
Consol. = period of triaxial consolidation
Comp. = period of triaxial compression

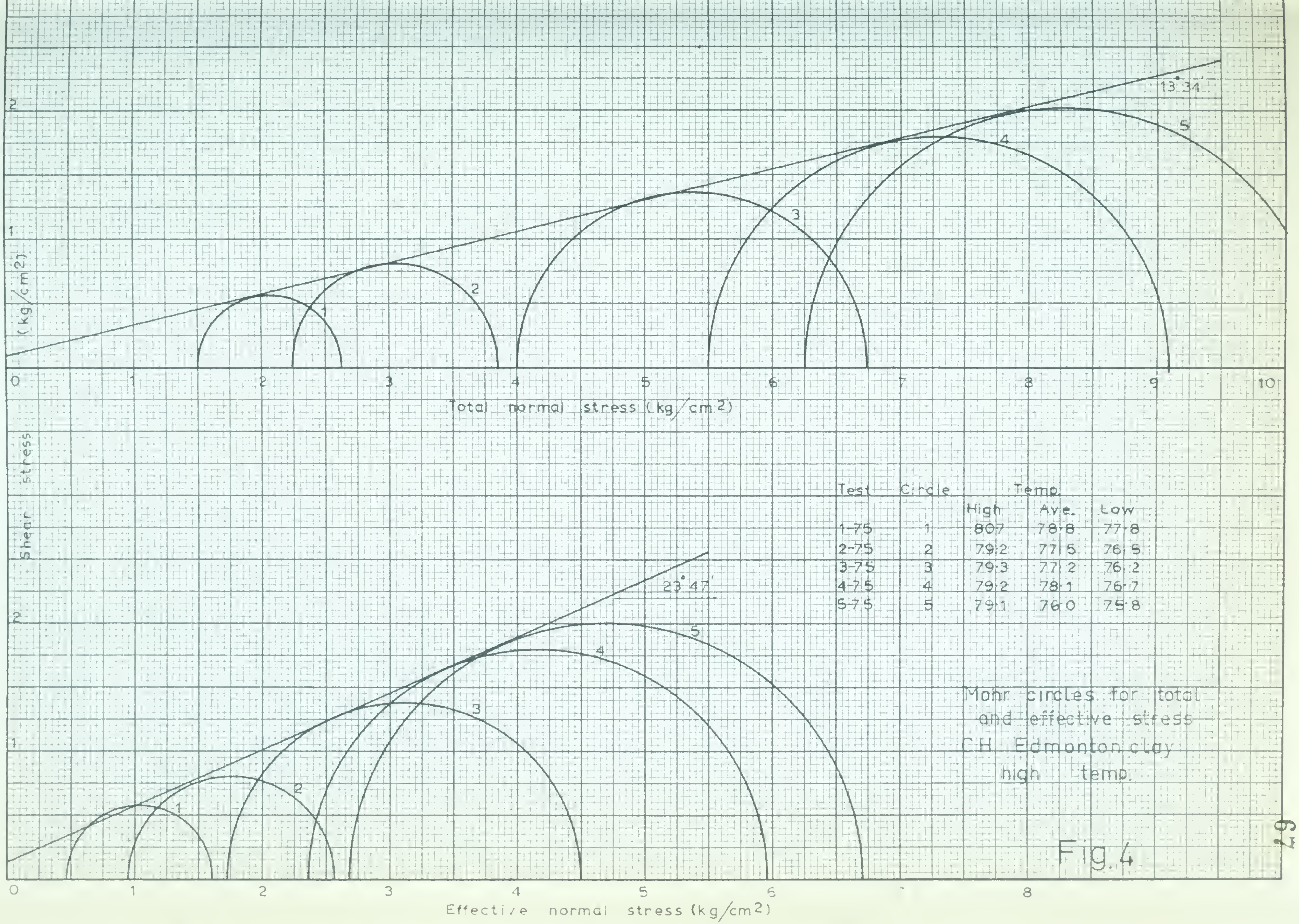
*Average temperature in the soil specimen. Figures in brackets above and below average value are the high and low value of temperature respectively.



Test	Circle	Temp High	Temp Ave.	Temp Low
1-35	1	37·5	36·9	35·5
2-35	2	37·5	37·2	36·1
3-35	3	37·8	37·0	36·0
4-35	4	38·0	37·5	36·0
4-35 rep.	4'	36·4	35·9	34·3
5-35	5	37·1	37·0	36·2

Mohr circles for total
and effective stress
C.H. Edmonton clay
low temp.

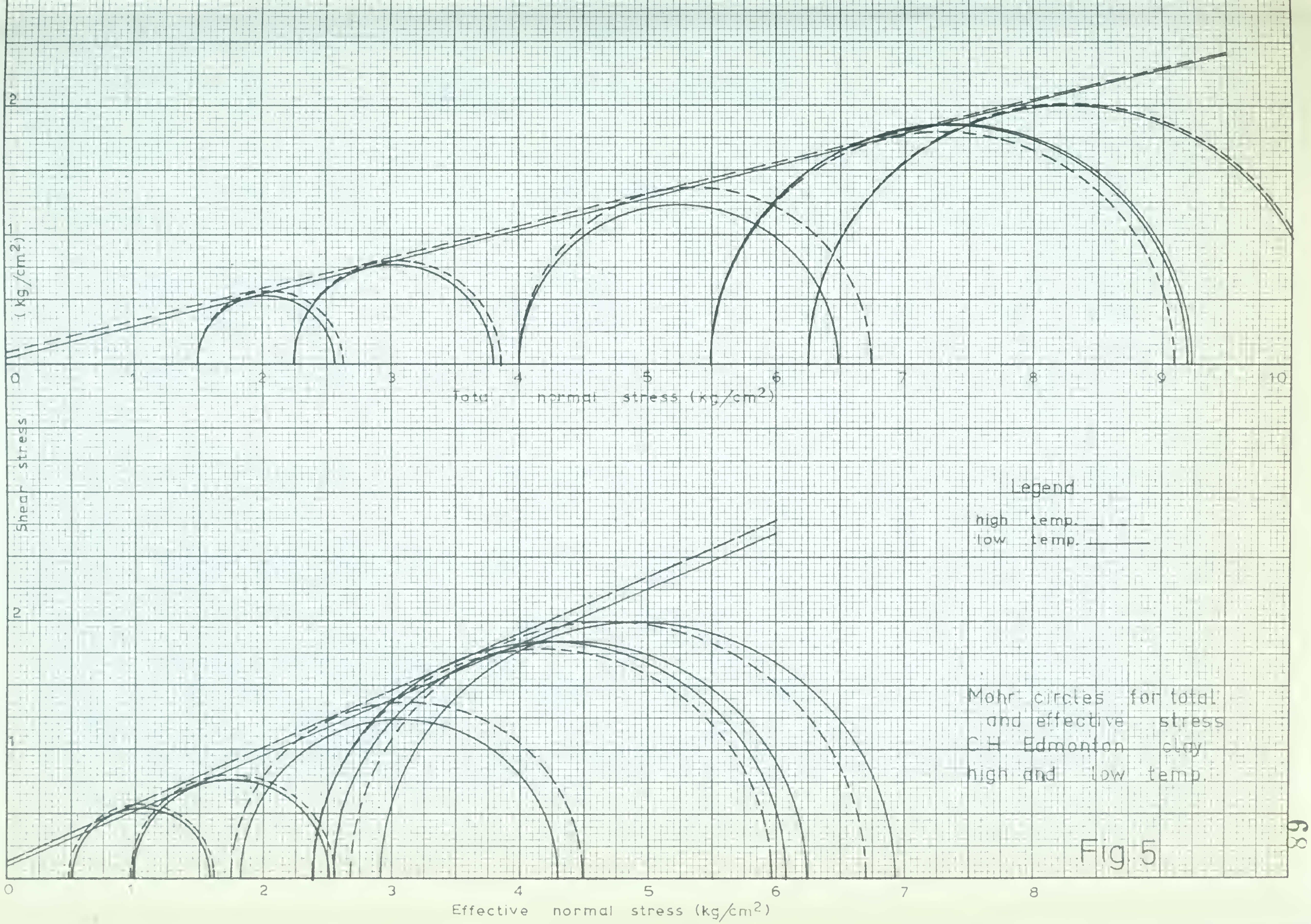
Fig. 3



Test	Circle	Temp High	Temp Ave.	Temp Low
1-75	1	80.7	78.8	77.8
2-75	2	79.2	77.5	76.5
3-75	3	79.3	77.2	76.2
4-75	4	79.2	78.1	76.7
5-75	5	79.1	76.0	75.8

Mohr circles for total
and effective stress
C.H. Edmonton clay
high temp.

Fig. 4



Mohr circles for total and effective stress C.H. Edmonton clay high and low temp.

Fig 5

TABLE 6

SUMMARY OF STRENGTH PARAMETERS OBTAINED FROM TRIAXIAL TESTS

	Test Series	Soil Used	c'	ϕ'	c	ϕ
(a)	High temperature	C H Edmonton clay	0.13	$23^\circ 47'$	0.09	$13^\circ 34'$
	Low temperature	C H Edmonton clay	0.10	$23^\circ 07'$	0.03	$14^\circ 02'$
	High and low temperature series combined	C H Edmonton clay	0.12	$23^\circ 23'$	0.06	$13^\circ 48'$
(b)	High temperature	Edmonton till	0.14	$29^\circ 36'$	0.12	$14^\circ 05'$
	Low temperature	Edmonton till	0.02	$31^\circ 54'$	0.04	$15^\circ 16'$
	High and low temperature series combined	Edmonton till	0.08	$30^\circ 45'$	0.08	$14^\circ 41'$
(c)	Thomsons tests at room temperature (Figure 8)	C H Edmonton clay	0.29	$19^\circ 45'$	0.33	$11^\circ 11'$
	Thomsons tests and high temperature series combined	C H Edmonton clay	0.23	$21^\circ 11'$	0.23	$12^\circ 26'$

parameters are in good agreement for the two test series, with c' being only 0.03 kg/cm^2 larger and ' being $0^{\circ}40'$ larger at the high temperature than at the low temperature. Similarly c is 0.06 kg/cm^2 larger at the high temperature than at the low temperature, but is $0^{\circ}28'$ smaller. These differences are small and when the Mohr circles for the two test series are superimposed upon each other, Figure 5, this becomes visually apparent.

It is difficult to assign a measure of reliability to such a limited number of tests however, an attempt was made to determine the experimental or random error invloved in the determination of the angle of shearing resistance. In this analysis the experimental error was computed for the condition of maximum obliquity for triaxial test No. 4-75; details are presented in Appendix I. Strictly speading this analysis will hold only for a cohesionless material in which case the rupture envelope is identical with the line starting at the origin of coordinates and is tangent to the Mohr circles, in a normal versus shear stress plot. It is presented however, to give some appreciation of the variations which can be expected due to random error inherent in the measuring apparatus alone.

The result of this analysis reveals that the effective angle of shearing resistance can be in error by $1^{\circ}22'$. This is greater than the difference obtained in the test series at the low and the high temperatures just

previously presented. The conclusion to be drawn is that the effect of temperature on the shear strength of the highly plastic clay is less than normal experimental error, and is therefore a difficult variable to study.

Moisture content versus logarithm of compressive strength.

Another instructive way of presenting the experimental data is by plotting moisture content versus logarithm of compressive strength as was first suggested by Rutledge (33). This has been done on Figure 6. In addition portions of the virgin compression branch, taken as the visual average from the void ratio versus logarithm of pressure plots of Figure 7, have been shown thereon. Figure 7 represents the graphical results of two standard one-dimensional consolidation tests performed on the C H Edmonton clay soil. Both of these tests were run on the same soil as used in the triaxial tests, and remoulded from about the liquid limit.

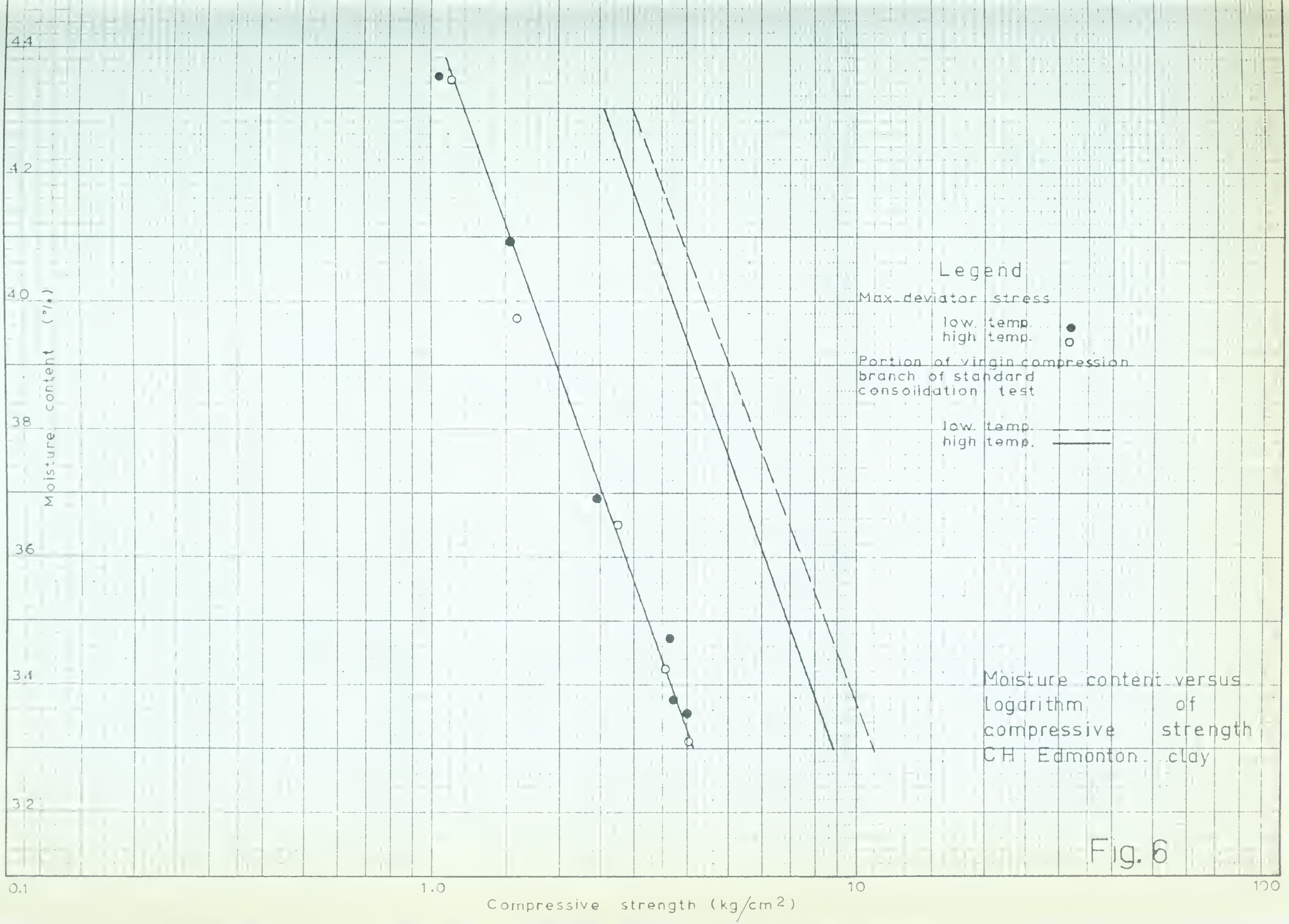
One test was performed at room temperature and the other in a walk-in freezer at a low temperature comparable to that in the triaxial test series. The temperatures holding in the distilled water surrounding the consolidating specimen were recorded on a strip chart, as in the case for the triaxial tests.

A summary of the average temperature, the high value, and the low value, for each load increment of the consolidation tests, is given in Table 7. A more detailed discussion of the results of these consolidation tests will

be given in a subsequent portion of this report.

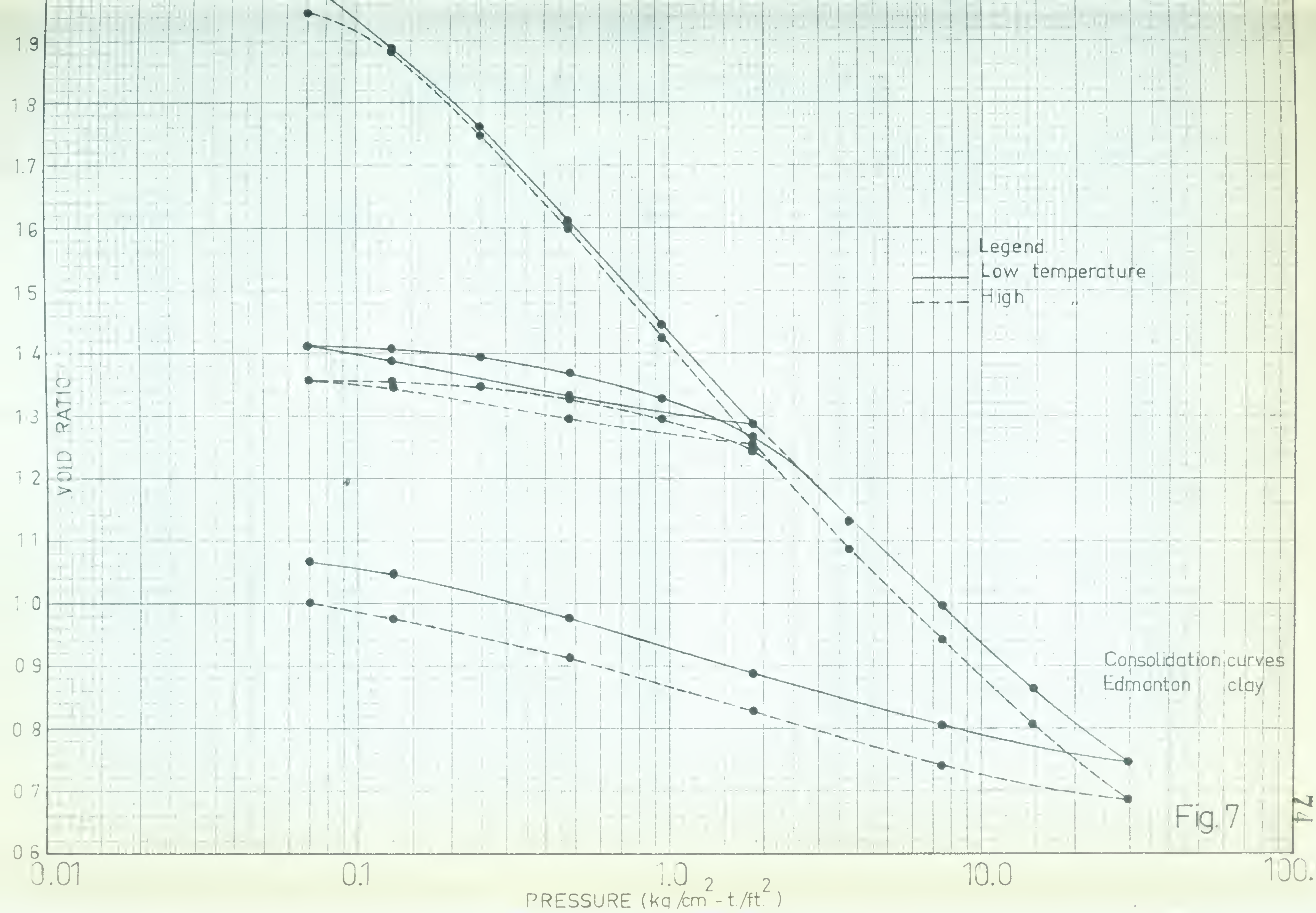
The temperature in the consolidation test at room temperature varied from a low value of 72.7°F to a high of 77.9°F. The low and high values recorded in the test at low temperature were 33.1°F and 35.9°F respectively. The corresponding low and high values in the triaxial tests for the series at high temperature (for the period of setting up on the loading press and compression) were 75.8°F and 80.7°F which is in the same order as for the consolidation tests. In the low temperature triaxial test series the low and high values recorded were 35.5°F and 38.0°F respectively, which is about 2°F higher than for the consolidation test.

Referring to Figure 6, it can be seen that there is a certain amount of scatter between the points representing the compressive strength (deviator stress) at failure (maximum principal effective stress ratio) and a best fit line. This scatter is inevitable even in tests on remoulded clays, Henkel (15). This best fit curve is very nearly identical in slope with the virgin compression branch of the consolidation test, run at room temperature, illustrating that there is an unique relationship between water content and strength for the soil tested. This is not a new hypothesis as it was first suggested by Rutledge (33) and has since been confirmed by many workers, for example, Taylor (38), Hvorslev (17), Bjerrum (5), Henkel (15), to mention a few. Of importance is the observation that there is no trend evident



Moisture content versus logarithm of compressive strength CH Edmonton clay

Fig. 6



Consolidation curves Edmonton clay

Fig. 7

TABLE 7

SUMMARY OF AVERAGE TEMPERATURES FOR CONSOLIDATION TESTS ON C H EDMONTON CLAY

	Low Temperature Test			High Temperature Test		
Load kg/cm^2	Temperature ^oF			Temperature ^oF		
	High	Average	Low	High	Average	Low
0.07	34.1	33.7	33.5	77.9	76.3	75.8
0.13	35.0	33.6	33.3	76.4	76.2	75.7
0.25	34.1	33.8	33.5	76.7	76.2	75.8
0.48	-	- *	-	-	- *	-
0.95	-	- *	-	-	- *	-
1.88	34.3	34.1	34.0	-	- *	-
0.48	34.6	34.3	33.8	77.2	76.4	76.1
0.13	34.7	34.2	34.1	77.5	77.0	76.7
0.07	35.0	34.1	33.3	77.9	77.4	76.2
0.13	35.3	34.9	34.1	77.2	77.0	75.6
0.25	35.8	35.0	34.8	77.2	77.2	77.2
0.48	35.1	34.6	34.1	77.7	77.1	76.7
0.95	34.3	33.6	33.4	76.9	76.5	76.2
1.88	34.6	33.5	33.1	77.2	76.6	75.8
3.75	35.9	33.6	33.3	76.4	75.9	75.2
7.49	33.8	33.6	33.1	76.0	75.3	74.7
14.96	34.0	33.8	33.6	76.2	75.3	74.7
29.91	33.8	33.6	33.5	75.7	75.4	75.2
7.49	34.5	34.0	33.7	76.0	75.5	74.7
1.88	34.2	34.0	33.6	76.1	75.6	74.9
0.48	34.3	34.1	34.1	76.7	76.0	75.3
0.13	34.6	34.1	33.7	76.4	75.9	75.4
0.07	34.1	33.8	33.5	76.7	74.4	72.7

*Strip chart used for commercial project before data could be obtained.

from the best fit line which could be charged to the effects of temperature. This further supports the earlier contention that this variable is very difficult to study and for the soil tested is of no important significance in the measured shear strength in terms of effective stress.

It is not implied here that this constitutes irrevocable evidence that temperature does not alter the physicochemical properties of the soil tested, but it does indicate that these effects are slight and for the range of temperature used, is very difficult to detect even for a very carefully performed series of triaxial tests.

Reference to Figures 4, 8, and 9, will now be made. Figure 8 is a plot of Mohr envelopes, in terms of total and effective stress determined by Thomson (42). This test series was run at room temperature on the same soil as used by the writer. The specimens were remoulded in an identical manner and exactly the same technique used by both workers. Apart from the modified triaxial cells used by the writer, the equipment used for the triaxial compression tests was the same in each instance. The data for plotting the Mohr circles of Figure 8, was generously offered by S. Thomson and is summarized in Table 8 for ready reference. The rupture envelopes of Figure 8 were fitted by a method of least squares as in the case for Figure 4. The Mohr circles and the respective rupture envelopes of Figures 4 and 8 have been superimposed upon each other to produce Figure 9. The values

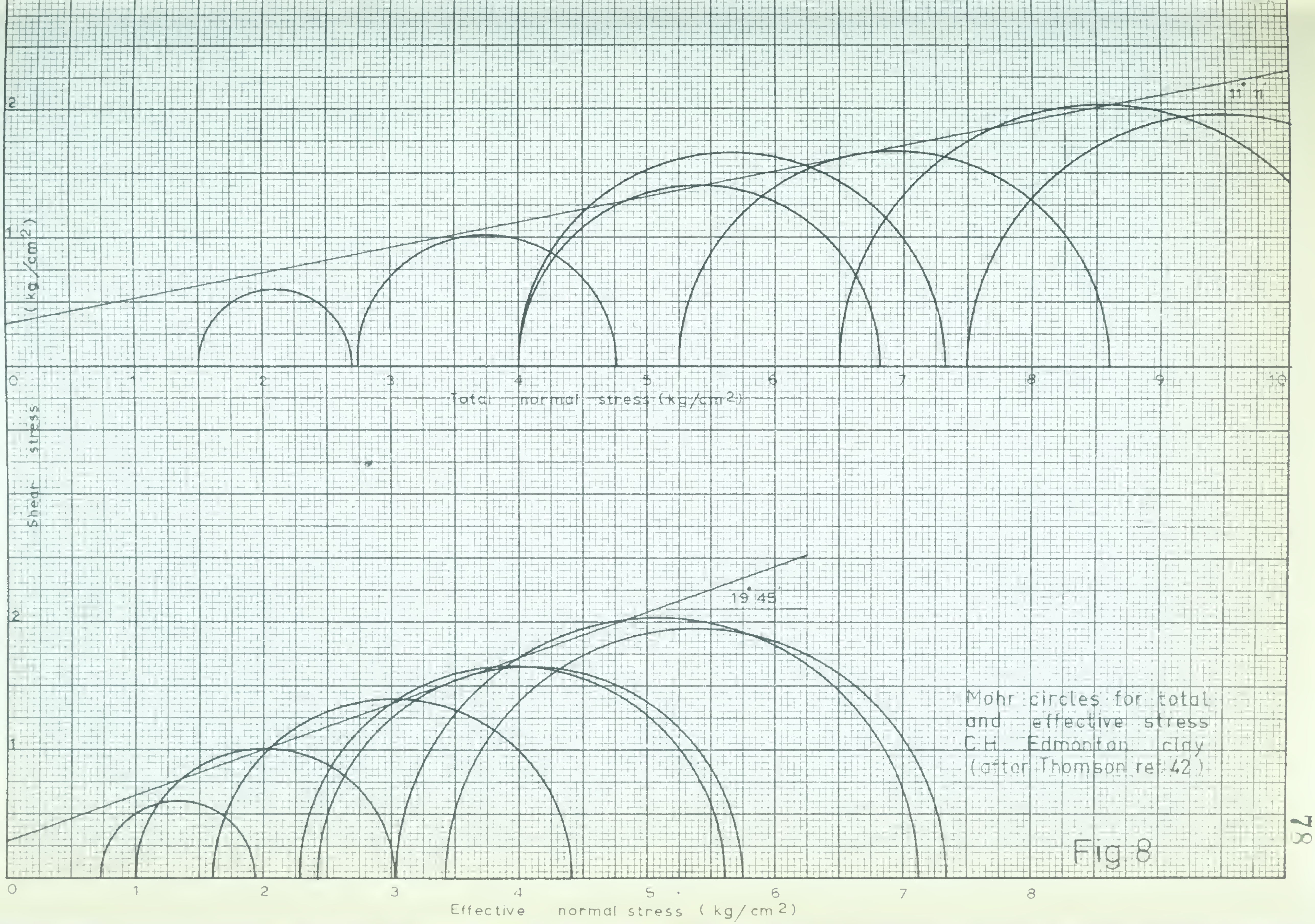
*TABLE 8

SUMMARY OF TRIAXIAL COMPRESSION TESTS ON REMOULDED C H EDMONTON CLAY AT ROOM TEMPERATURE

σ_c kg/cm^2	W_i %	W_f %	e_f	S_f %	σ'_{1f} kg/cm^2	σ'_{3f} kg/cm^2	$\sigma_1 - \sigma_3$ kg/cm^2	P_p kg/cm^2	μ %	$\bar{A}$ %	**Temperature ^oF	
											High	Low
1.5	52.2	42.3	1.20	-	1.93	0.73	1.20	0.77	8.75	61.5	-	-
2.75	52.5	38.3	1.09	97.5	3.02	1.01	2.01	1.74	8.6	86.8	-	-
4.0	51.1	34.4	0.96	99.2	5.75	2.43	3.32	1.57	9.75	47.2	-	-
4.0	52.1	36.6	1.04	98.1	4.41	1.60	2.81	2.40	13.5	85.4	77.0	73.4
5.25	54.1	35.3	1.01	97.0	5.62	2.27	3.35	2.98	10.0	89.0	83.1	75.7
6.50	52.5	33.3	0.96	97.1	7.13	3.04	4.09	3.46	10.0	84.6	83.7	79.9
7.50	53.9	32.7	0.93	97.2	7.34	3.42	3.92	4.08	10.5	104.1	78.4	72.5

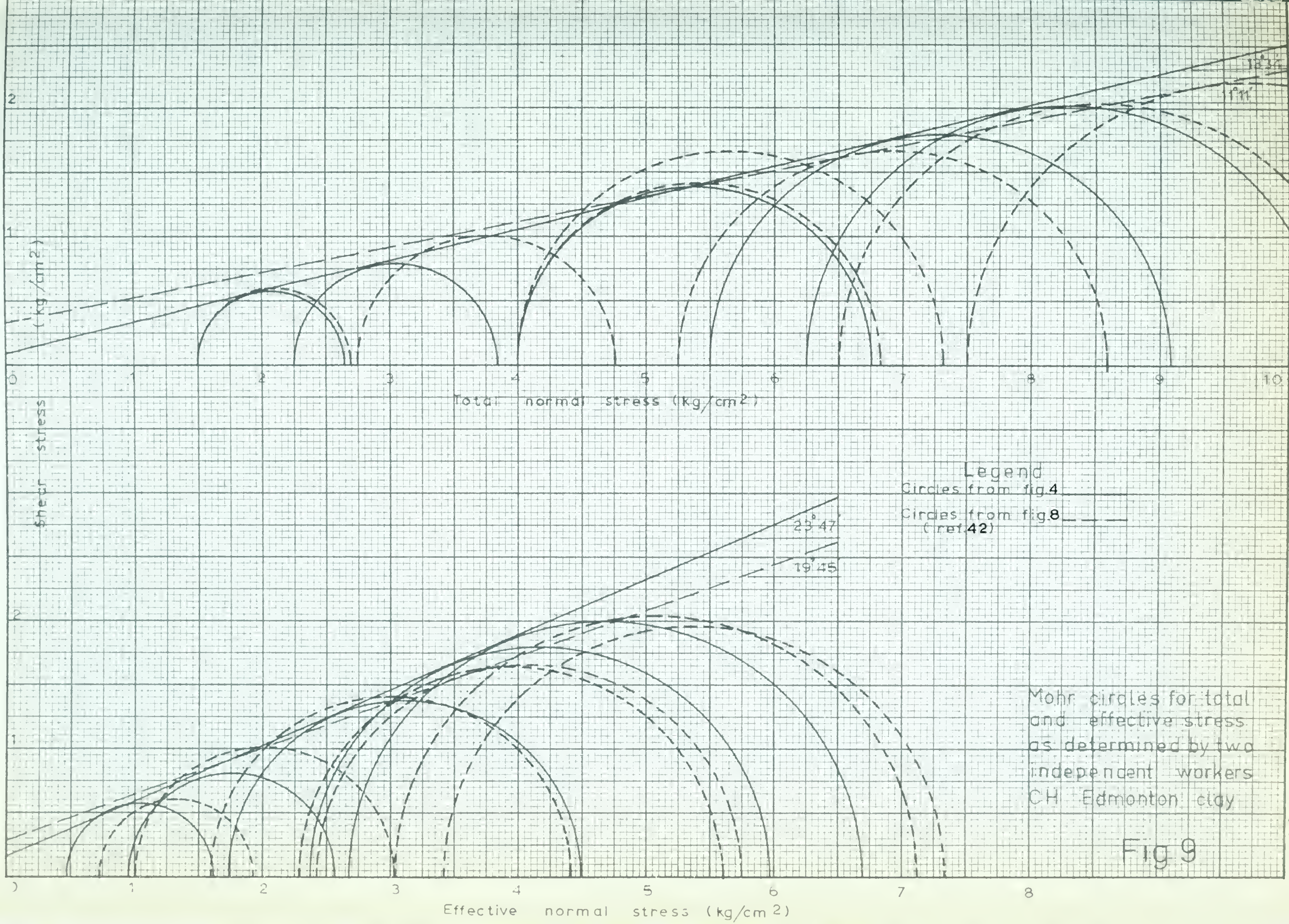
*After Thomson (42)

**Room temperatures during triaxial test.



Mohr circles for total and effective stress C.H. Edmonton clay (after Thomson ref. 42)

Fig. 8



Mohr circles for total and effective stress as determined by two independent workers
CH Edmonton clay

Fig 9

of the shear strength parameters in terms of total and effective stress for Figures 8 and 9 are summarized in Table 6 (c).

The ambient air temperature for four of the seven tests performed by Thomson ranged from a low value of 72.5°F to a high value of 83.7°F. No record was kept for the other three tests.

The value of ϕ' determined by the writer (23°47') is 4°02' larger than that determined by Thomson (19°45'). The value of c' determined by the writer (0.13 kg/cm^2) is 0.16 kg/cm^2 smaller than that determined by Thomson (0.29 kg/cm^2). The difference in ϕ' appears to be greater than just normal experimental error. Since both of these test series were run at approximately the same order of temperature it is reasonable to draw the conclusion that the effect of temperature can be completely masked by uncontrollable operator errors.

Three dimensional consolidation.

Figures 10 to 14 inclusive are the results of the three-dimensional consolidation achieved in the triaxial cells for the period preceding the compression portion of the triaxial tests. The consolidation was measured by the amount of water expelled from the specimen after application of the confining pressure. Each figure shows the consolidation characteristics both at the high and low temperature for the same confining pressure. The curves have been reduced to a

common datum at time equals 6 seconds after drainage was begun, for direct comparison. The times for theoretical 100% consolidation and the volume of water expelled are summarized in Table 9.

In addition to the fact that there is only a very limited amount of experimental results, from which one can draw firm conclusions, there is another limitation imposed upon the interpretation of the results. This fact being that the curves may not be a true representation of the water expelled from the specimen. Every precaution was taken to ensure that there was no air entrapped between the soil specimen and the enclosing membrane by saturating the surrounding filter strips and the porous drainage disc upon which the specimen sat. There is the possibility however, that excess water of varying amounts could be introduced in the process of applying the filter drainage strips. Another likely source of error is the fact that it is not possible to introduce exactly the same amount of water into the soil specimens by means of the internal wool drains. In spite of these limitations it is felt that the trends exhibited represent the effects of temperature on the three-dimensional consolidation characteristics.

The curves have the same general shape as that observed for the one-dimensional consolidation tests run on the same soil. The times for theoretical 100% consolidation are, with one exception, greater for the series at low

TABLE 9

SUMMARY OF THREE-DIMENSIONAL CONSOLIDATION FOR TRIAXIAL TESTS ON C H EDMONTON CLAY

Test No.	Confining pressure kg/cm^2	Time for theoretical 100% consolidation min	Water expelled cm^3	Temperature* ^oF		
				High	Average	Low
1-35	1.5	230	10.69	37.2	36.7	34.8
2-35	2.25	215	11.80	36.8	36.3	33.0
3-35	4.0	190	13.79	37.0	36.5	33.6
4-35 (rep)	5.5	235	19.41	37.2	35.9	30.5
5-35	6.25	235	18.91	37.0	36.7	36.0
1-75	1.5	140	10.86	80.8	78.7	77.8
2-75	2.25	160	12.65	79.8	79.1	78.1
3-75	4.0	190	16.00	76.7	76.3	75.7
4-75	5.5	155	18.81	78.2	76.9	76.3
5-75	6.25	160	19.26	79.1	77.7	76.5

*Temperatures are for the period of consolidation.

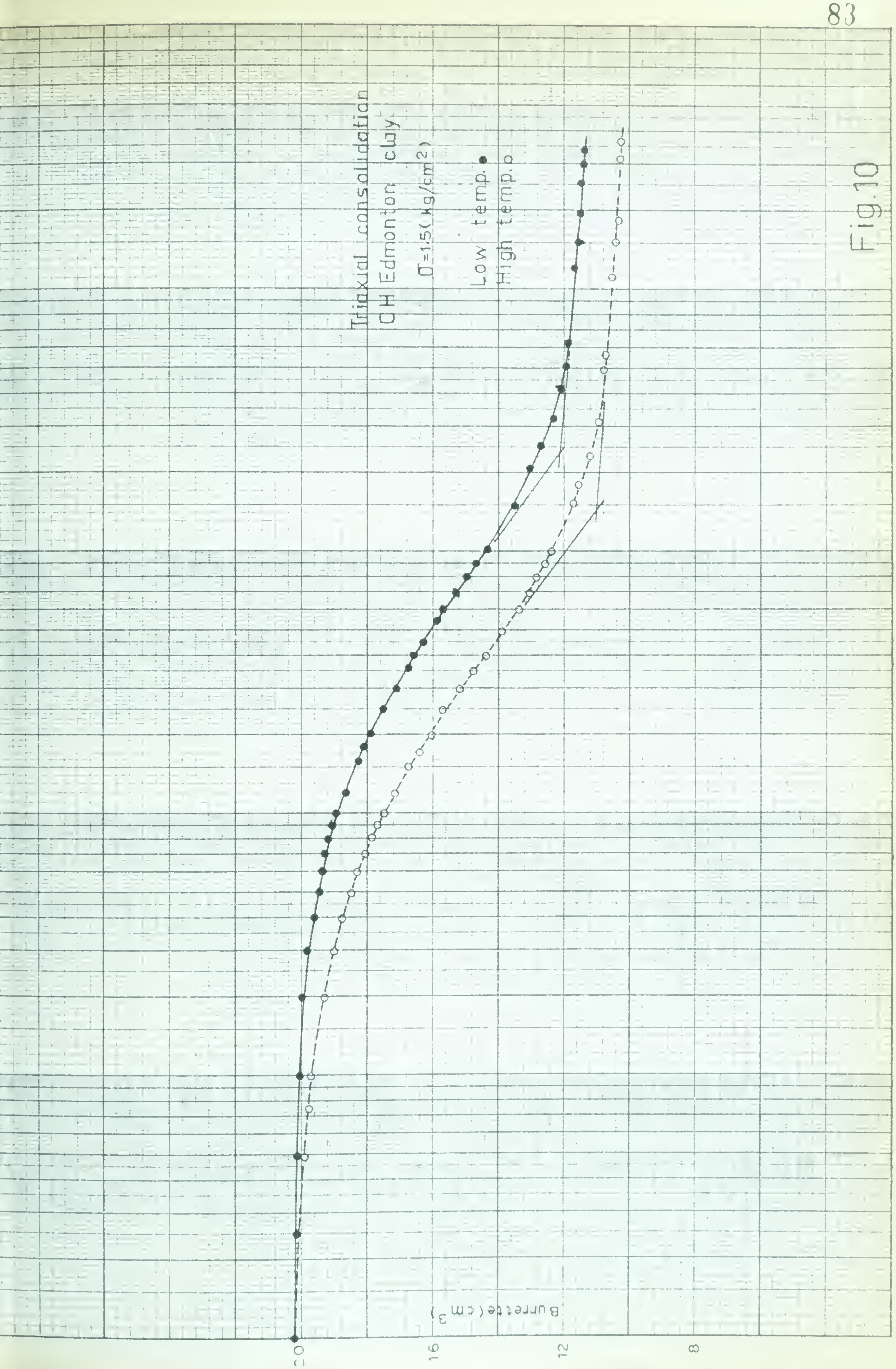

Triaxial consolidation
CH Edmonton clay
σ=1.5(kg/cm^2)
Low temp. ●
High temp. ○
Burrette(cm^3)
20
16
12
8
Time (min)
0.1
1.0
10
100
1000

Fig.10

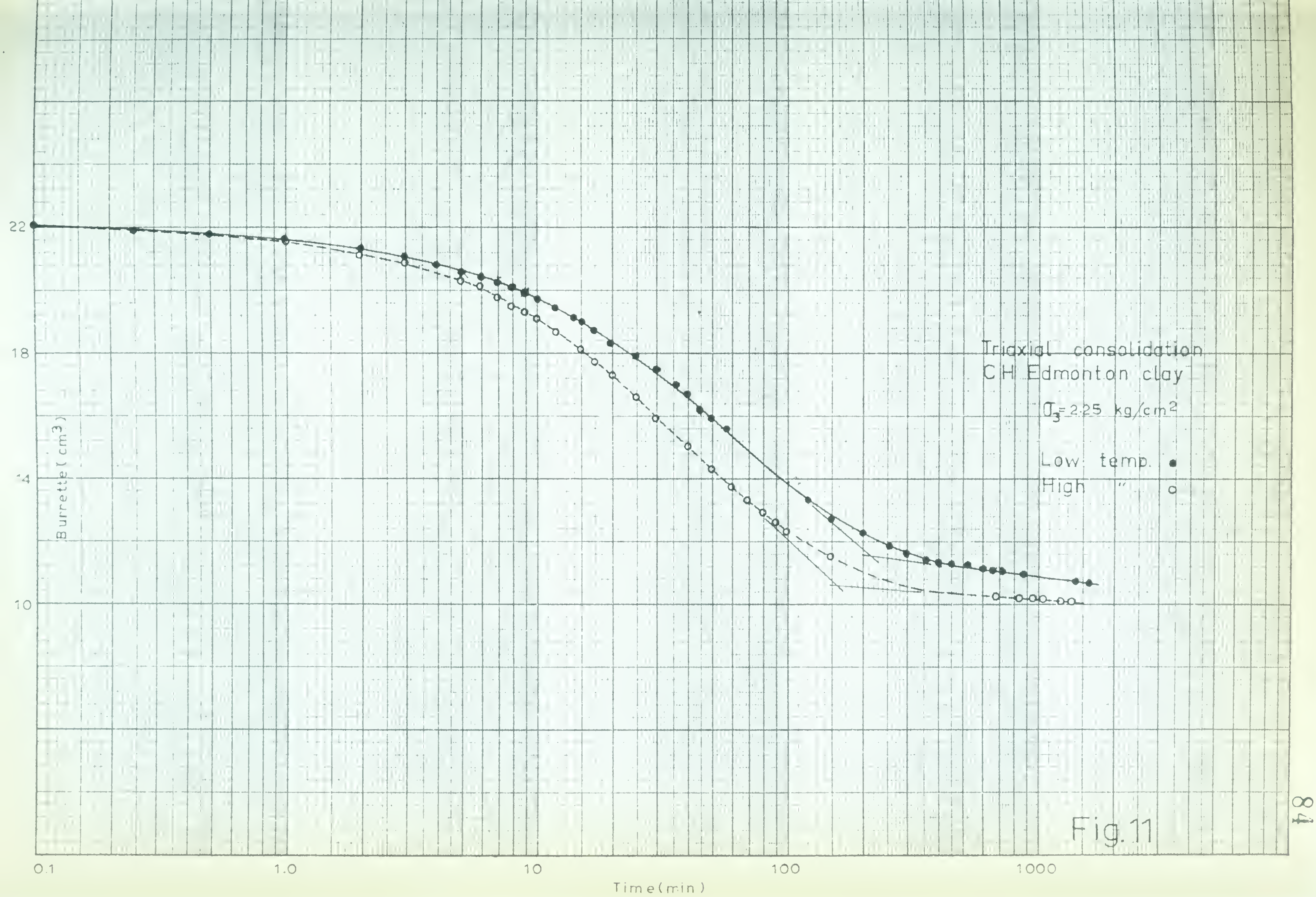

Triaxial consolidation
C H Edmonton clay
$\sigma_3 = 2.25$ kg/cm²
Low temp. ●
High " ○
Burrette (cm³)
22
18
14
10
Time (min)
0.1
1.0
10
100
1000

Fig.11

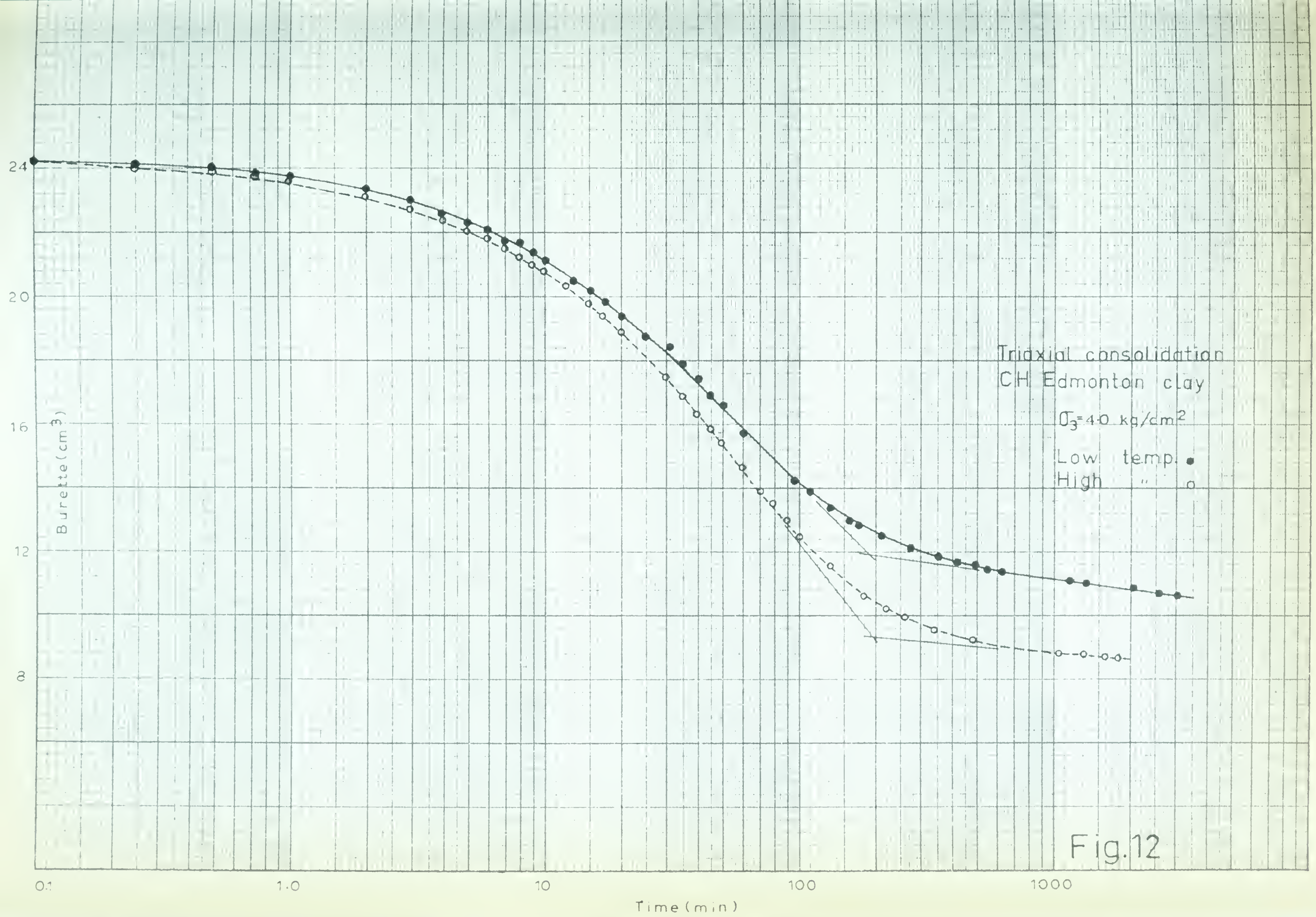

Triaxial consolidation
CH Edmonton clay
σ_3=4.0 kg/cm^2
Low temp. ●
High " ○
24
20
16
12
8
Burette (cm^3)
0.1
1.0
10
100
1000
Time (min)

Fig.12

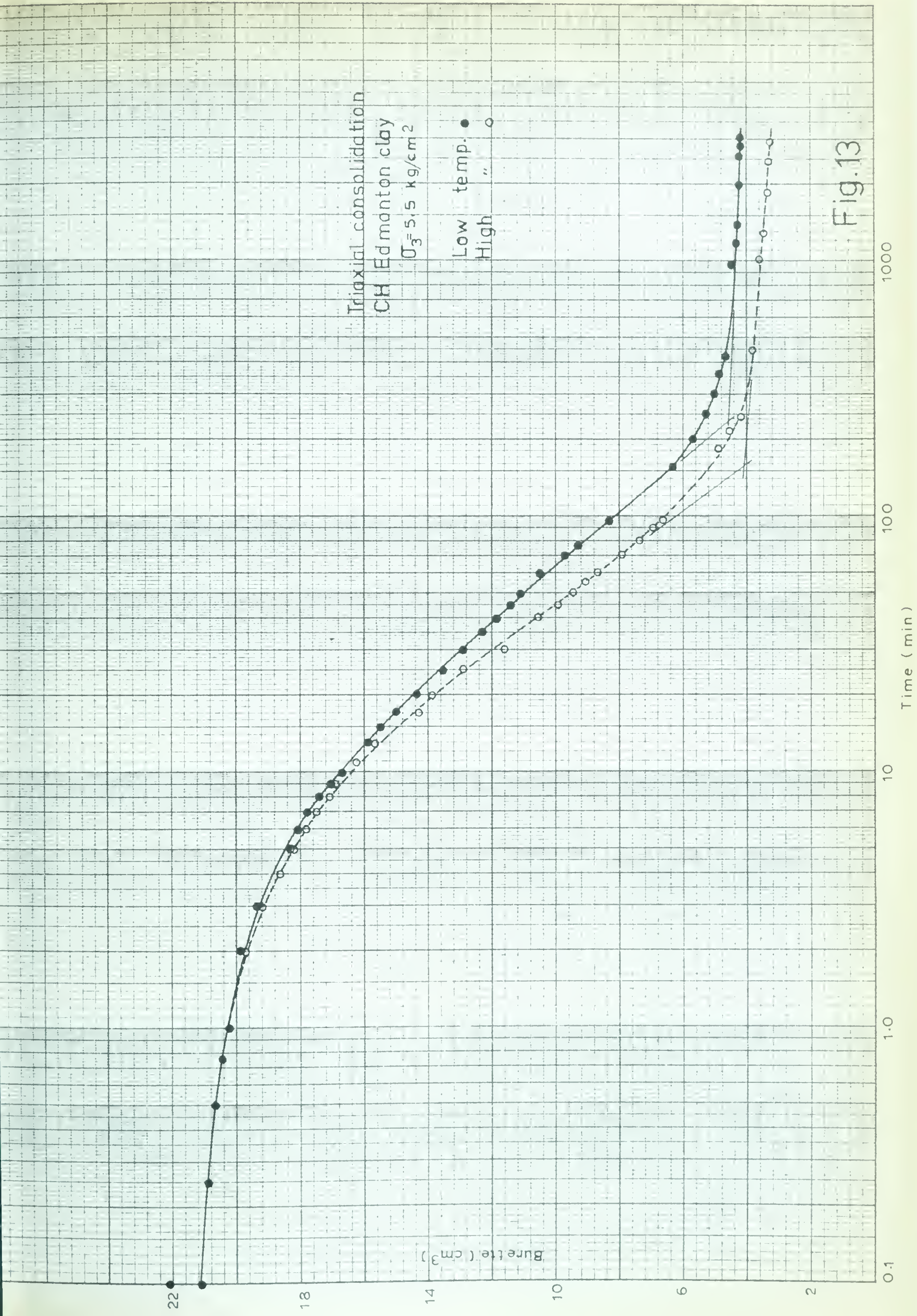

Triaxial consolidation
CH Edmonton clay
$\sigma_3 = 5.5$ kg/cm^2
Low temp. ●
High " ○
Burette (cm^3)
22
18
14
10
6
2
Time (min)
0.1
1.0
10
100
1000

Fig.13

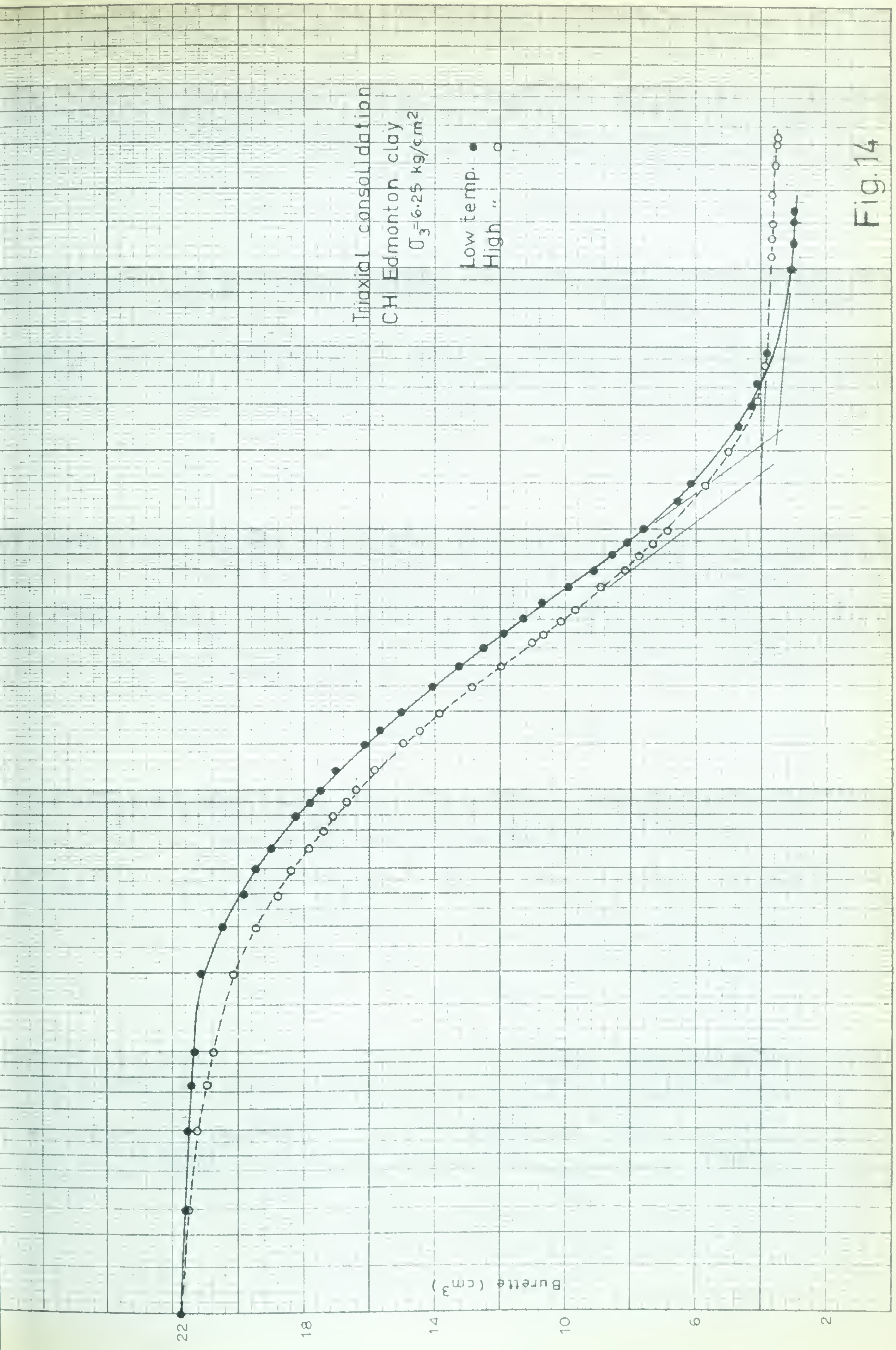

Triaxial consolidation
CH Edmonton clay
$\sigma_3 = 6{\cdot}25$ kg/cm^2
Low temp. ●
High " ○
Burette (cm^3)
22
18
14
10
6
2
Time (min)
0.1
1.0
10
100
1000

Fig.14

temperature than at the high temperature; this same phenomenon being observed in the case of the one-dimensional consolidation tests. At four of the five test lateral pressures there is a tendency for the portion of the secondary compression branch to be steeper at the low temperature. Quantitative values of the slopes of the secondary compression branches are summarized in Table 9 (a). Departure from this trend is shown on Figure 13 in which case the slopes of the secondary compression branches are the same for both temperatures investigated.

It is evident that the rate of consolidation is affected by temperature change. However, the amount of consolidation for two tests, at the same lateral pressure, and for the same times, remains sensibly the same and should not result in a marked difference in strength characteristics.

Results Obtained With Edmonton Till

Triaxial compression tests.

Table 10 is a summary of the triaxial compression test results performed on the Edmonton till at the low temperature and Table 11 for the test series at the high temperature. From these results the Mohr circles shown on Figures 15 and 16 have been constructed. Figure 15 shows the Mohr circles for the test series at low temperature and

TABLE 9 (a)

SLOPES OF SECONDARY COMPRESSION BRANCH FOR THREE-DIMENSIONAL CONSOLIDATION ON C H EDMONTON CLAY AND EDMONTON TILL

Consolidation Pressure (kg/cm^2)	*Slope of secondary compression branch		Soil
	High Temp.	Low Temp.	
1.5	0.6	1.6	C H Clay
2.25	0.6	1.0	C H Clay
4.0	0.7	1.0	C H Clay
5.5	0.5	0.5	C H Clay
6.25	0.3	0.5	C H Clay
1.5	0.3	0.5	Till
2.25	0.3	0.3	Till
4.0	0.2	0.3	Till
5.5	0.2	0.2	Till
6.25	0.2	0.2	Till

*Change in burette reading per log cycle.

Figure 16 are those for the series at high temperature. Figure 17 is a superposition of the above two figures for ready comparison. Values of cohesion and angle of shearing resistance, in terms of both total and effective stress, for both test series are summarized in Table 6 (b), presented in the immediately preceding section. A complete record of temperatures for the series at the high temperature is not available. For both tests 4-75 T and 5-75 T, the temperature recorder failed shortly after the compression portion of the test was begun.

The rupture envelope for both total and effective stresses is well defined for the test series at the low temperature, Figure 15. The scatter from the computed rupture envelope for the series at the high temperature is much more pronounced, particularly so for effective stresses, Figure 16. Here again it is clearly evident that the measured pore pressures are not correct, since if the deviations were charged to the rather large variation in temperature at the given range, then there should have resulted in more scatter for the series at low temperature. The spread in temperature at the low range was 6.6°F and at the high range it was 4.3°F.

Examination of Table 6 (b) reveals that ϕ' is 2°18' larger for the tests at the low temperature compared with the series at high temperature, whereas c' is 0.12 kg/cm^2 smaller. In terms of total stress ϕ is 1°11' larger and c is 0.08 kg/cm^2 smaller at the low temperature than at the high temperature.

TABLE 10

SUMMARY OF TRIAXIAL COMPRESSION TESTS ON REMOULDED EDMONTON TILL AT LOW TEMPERATURE

Test No.	σ_c kg/cm^2	W_i		W_f	e_f	S_f	$\sigma 1_f$ kg/cm^2	$\sigma 3_f$ kg/cm^2	$\sigma_1 - \sigma_3$ kg/cm^2	P_p kg/cm^2	μ %	$\bar{A}$ %	Temperature* °F	
		From Trim.	Calc.										Consol.	Comp.
1-35T	1.5	27.02	27.75	21.79	0.61	97.1	1.65	0.53	1.12	0.97	11.0	86.6	(36.4) 35.7 (33.4)	(37.2) 36.6 (34.9)
2-35T	2.25	24.42	25.26	20.29	0.57	96.3	2.42	0.67	1.75	1.58	11.0	90.3	(37.0) 36.2 (33.5)	(37.6) 37.1 (36.4)
3-35T	4.0	24.47	24.96	18.34	0.52	95.2	4.26	1.30	2.96	2.70	11.5	91.2	(37.6) 36.9 (34.0)	(38.2) 37.5 (35.2)
4-35T	5.5	25.23	25.50	17.84	0.50	96.2	5.81	1.77	4.04	3.73	10.0	92.3	(37.3) 36.8 (33.5)	(37.7) 36.6 (32.6)
5-35T	6.25	25.12	25.47	17.48	0.49	97.7	6.54	2.00	4.54	4.25	10.0	93.6	(37.5) 36.7 (32.2)	(37.5) 36.5 (31.6)

Abbreviations:

Trim. = trimmings
Calc. = calculated from final condition
Consol. = period of triaxial consolidation
Comp. = period of triaxial compression

*Average temperature in the soil specimen. Figures in brackets above and below average value are the high and low value of temperature respectively.

TABLE 11

SUMMARY OF TRIAXIAL COMPRESSION TESTS ON REMOULDED EDMONTON TILL AT HIGH TEMPERATURE

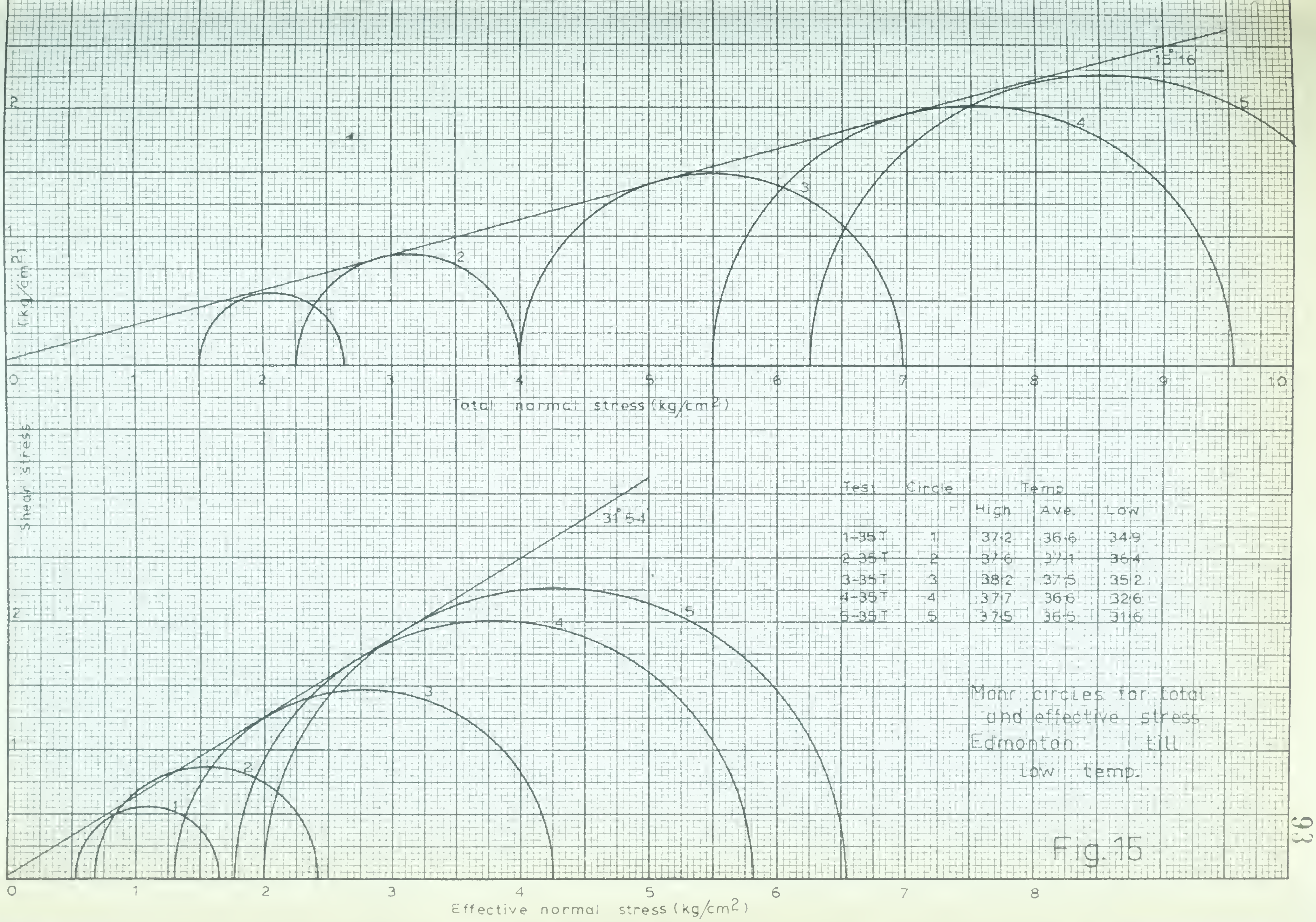
Test No.	σ_c kg/cm^2	W_i		W_f	e_f	S_f	σ'_{1f} kg/cm^2	σ'_{3f} kg/cm^2	$\sigma_1-\sigma_3$ kg/cm^2	P_p kg/cm^2	μ %	$\bar{A}$ %	Temperature* °F	
		From Trim.	Calc.										Consol.	Comp.
1-75T	1.5	26.15	26.65	21.46	0.61	97.0	1.73	0.52	1.21	0.98	9.5	81.0	(76.9) 76.2 (75.7)	(79.3) 77.7 (76.9)
2-75T	2.25	24.05	25.15	20.14	0.56	96.7	2.37	0.60	1.77	1.65	11.5	93.2	(79.7) 77.3 (76.0)	(81.2) 80.0 (79.0)
3-75T	4.0	26.02	27.07	19.15	0.54	96.4	3.94	1.08	2.86	2.92	11.0	102.1	(81.1) 78.1 (76.1)	(81.2) 79.9 (78.7)
4-75T	5.5	26.44	27.45	18.15	0.52	95.4	5.71	1.79	3.92	3.71	11.0	94.6	(77.8) 77.2 (76.8)	**
5-75T	6.25	26.26	27.11	17.91	0.51	95.1	6.34	2.03	4.31	4.22	11.5	97.8	(78.0) 77.4 (76.9)	**

Abbreviations:

Trim. = trimmings
Calc. = calculated from final condition
Consol. = period of triaxial consolidation
Comp. = period of triaxial compression

*Average temperature in the soil specimen. Figures in brackets above and below average value are the high and low value of temperature respectively.

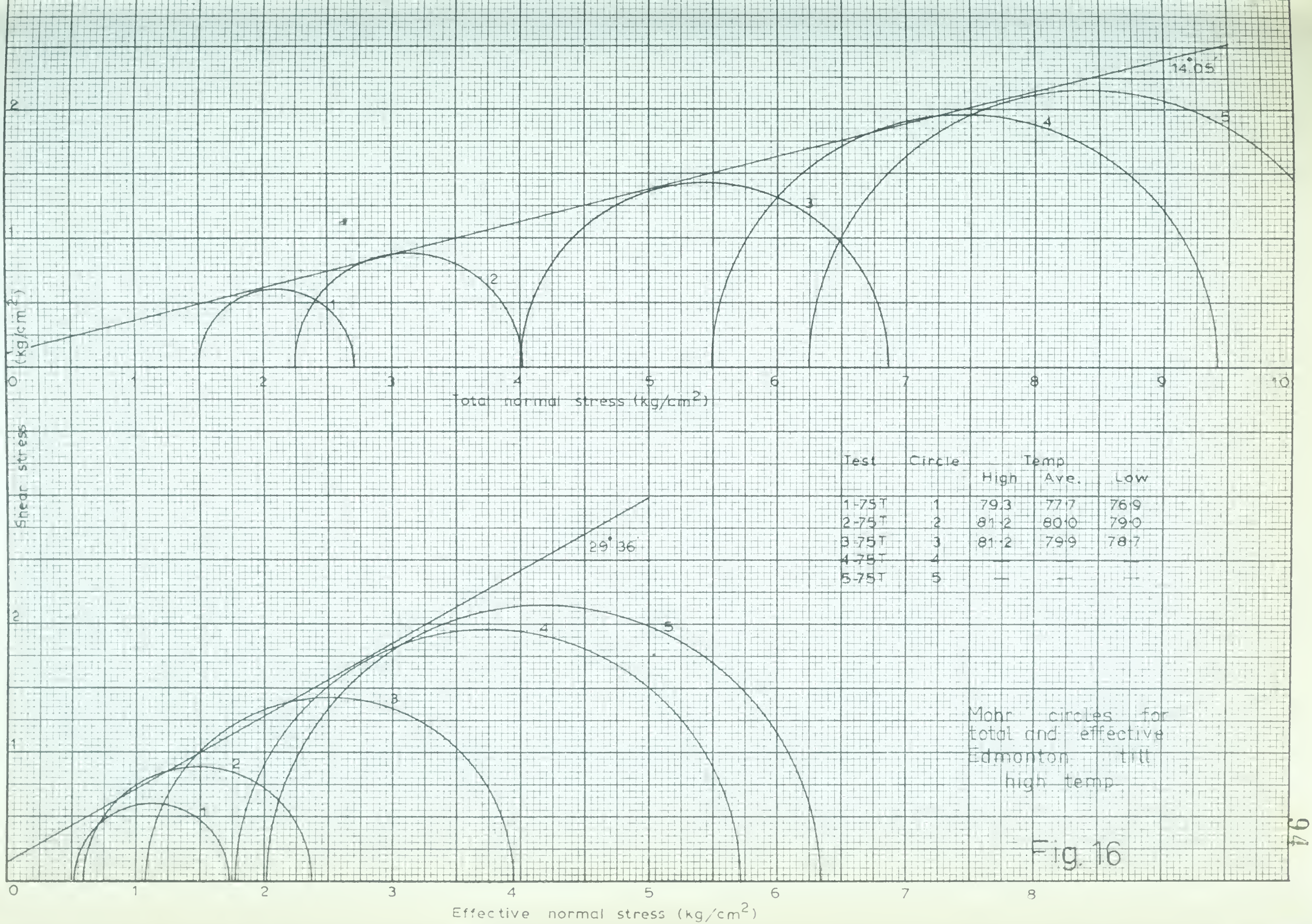
**Recorder broken for period of triaxial compression test.



Test	Circle	Temp High	Temp Ave.	Temp Low
1-35T	1	37.2	36.6	34.9
2-35T	2	37.6	37.1	36.4
3-35T	3	38.2	37.5	35.2
4-35T	4	37.7	36.6	32.6
5-35T	5	37.5	36.5	31.6

Mohr circles for total
and effective stress
Edmonton till
low temp.

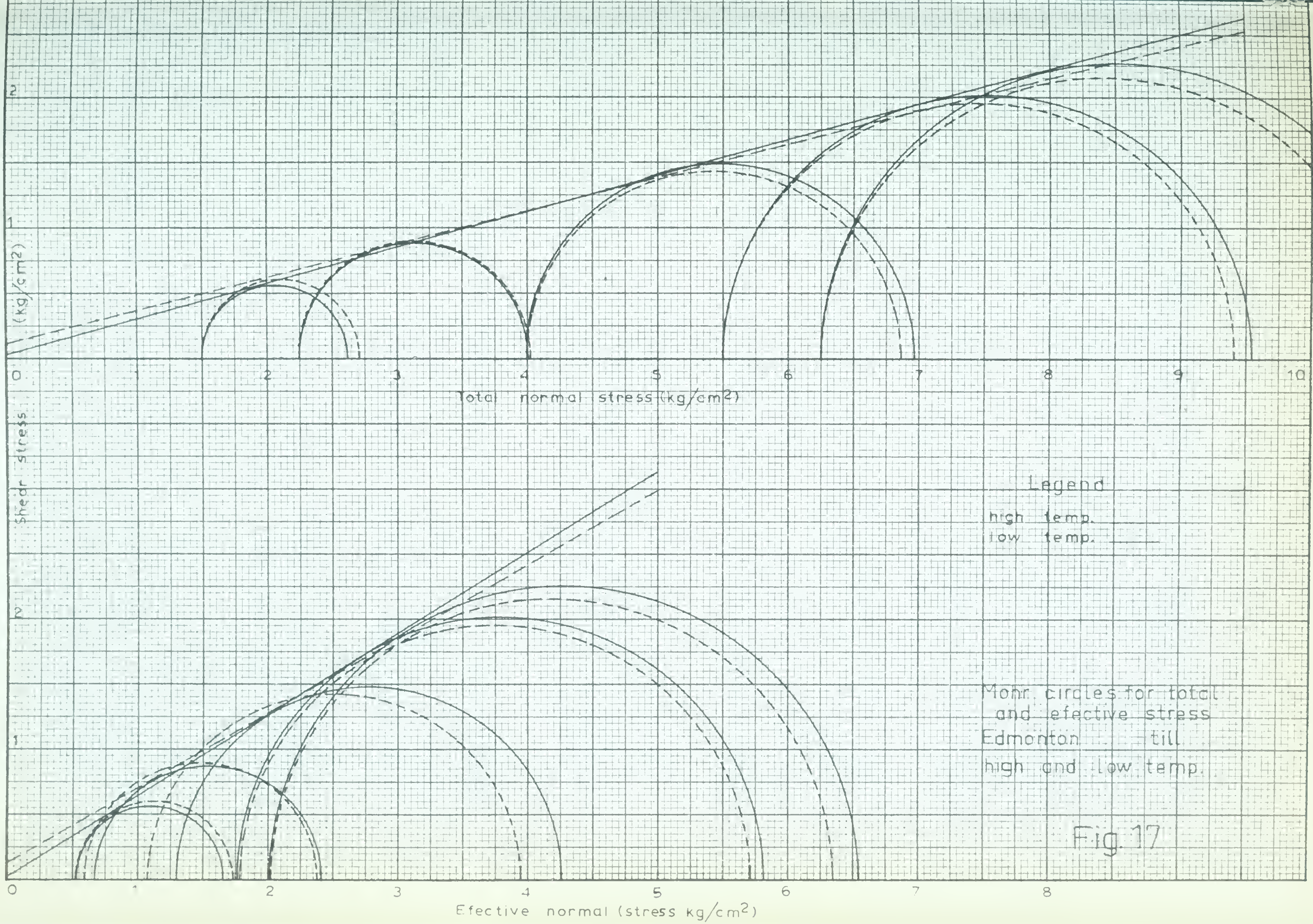
Fig. 15



Test	Circle	Temp High	Temp Ave.	Temp Low
1-75T	1	79.3	77.7	76.9
2-75T	2	81.2	80.0	79.0
3-75T	3	81.2	79.9	78.7
4-75T	4	—	—	—
5-75T	5	—	—	—

Mohr circles for
total and effective
Edmonton till
high temp.

Fig. 16



Mohr circles for total and efective stress Edmonton till high and low temp.

Fig. 17

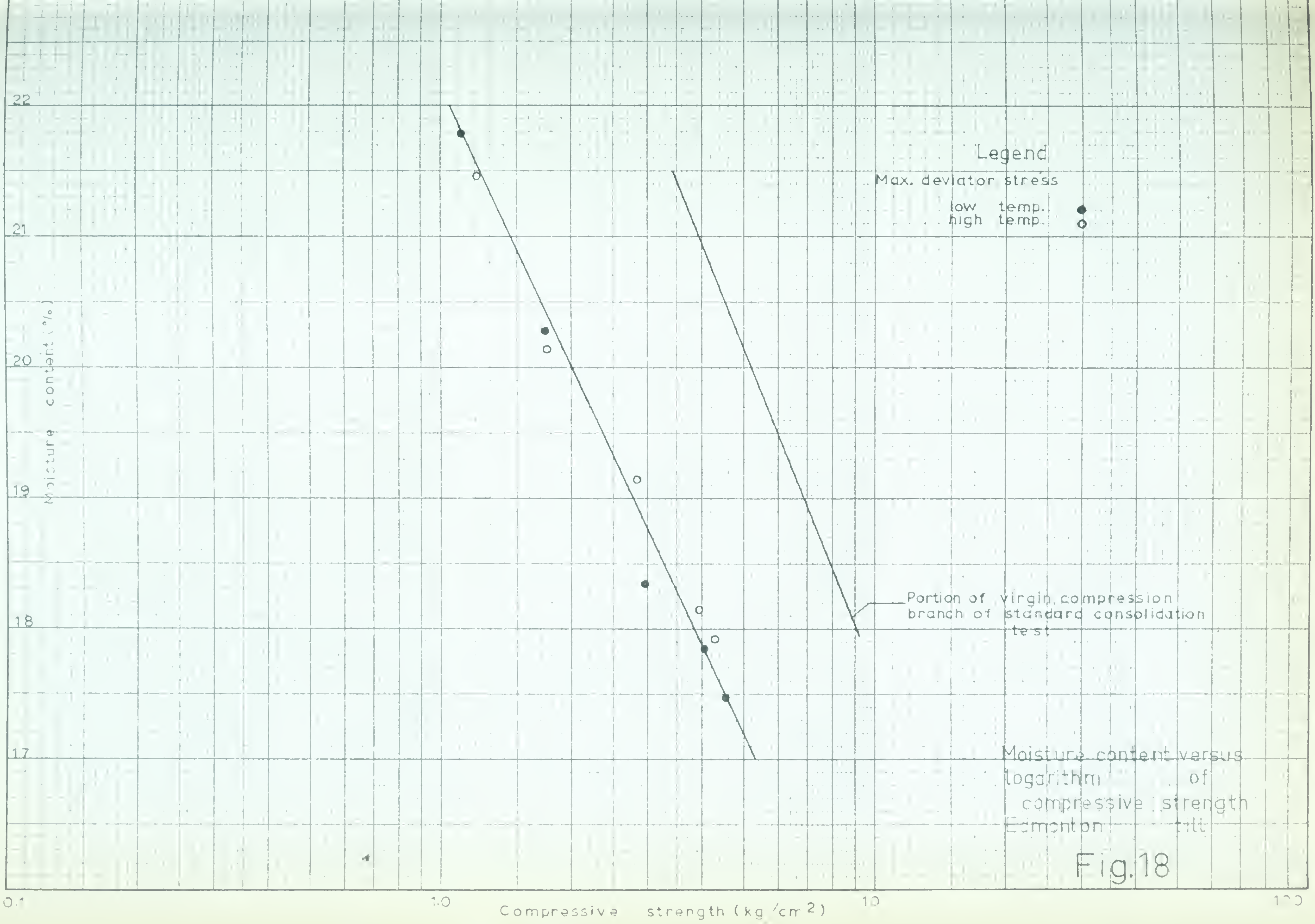
In the case of effective stress the difference in ϕ' is in the order of normal experimental error. Furthermore the difference is in a direction opposite that obtained in the test series run on the highly plastic clay. Any surface activity which could be caused by variation in temperature should have been more marked in the C H Edmonton clay because of its higher clay content. This is because the seat of surface activity originates within the clay fraction. And even though the clay content of the Edmonton till is much less, any trend due to temperature variation should have been in the same direction as that observed in the highly plastic clay soil.

It must therefore be concluded that any physico-chemical effects due to variation in temperature are not important in the determination of the shearing strength of the soil tested.

It could be argued that for both soil types tested there is an increase in strength as reflected by an increase in angle of shearing resistance, in terms of total stress. However, this increase is small.

Moisture content versus logarithm of compressive strength.

The results of the triaxial tests on the Edmonton till are also presented in the form of a plot of moisture content at failure versus logarithm of deviator stress at failure, Figure 18. On this plot is also shown a portion of the virgin compression branch of a standard one-dimensional



Moisture content versus logarithm of compressive strength Edmonton till

Fig.18

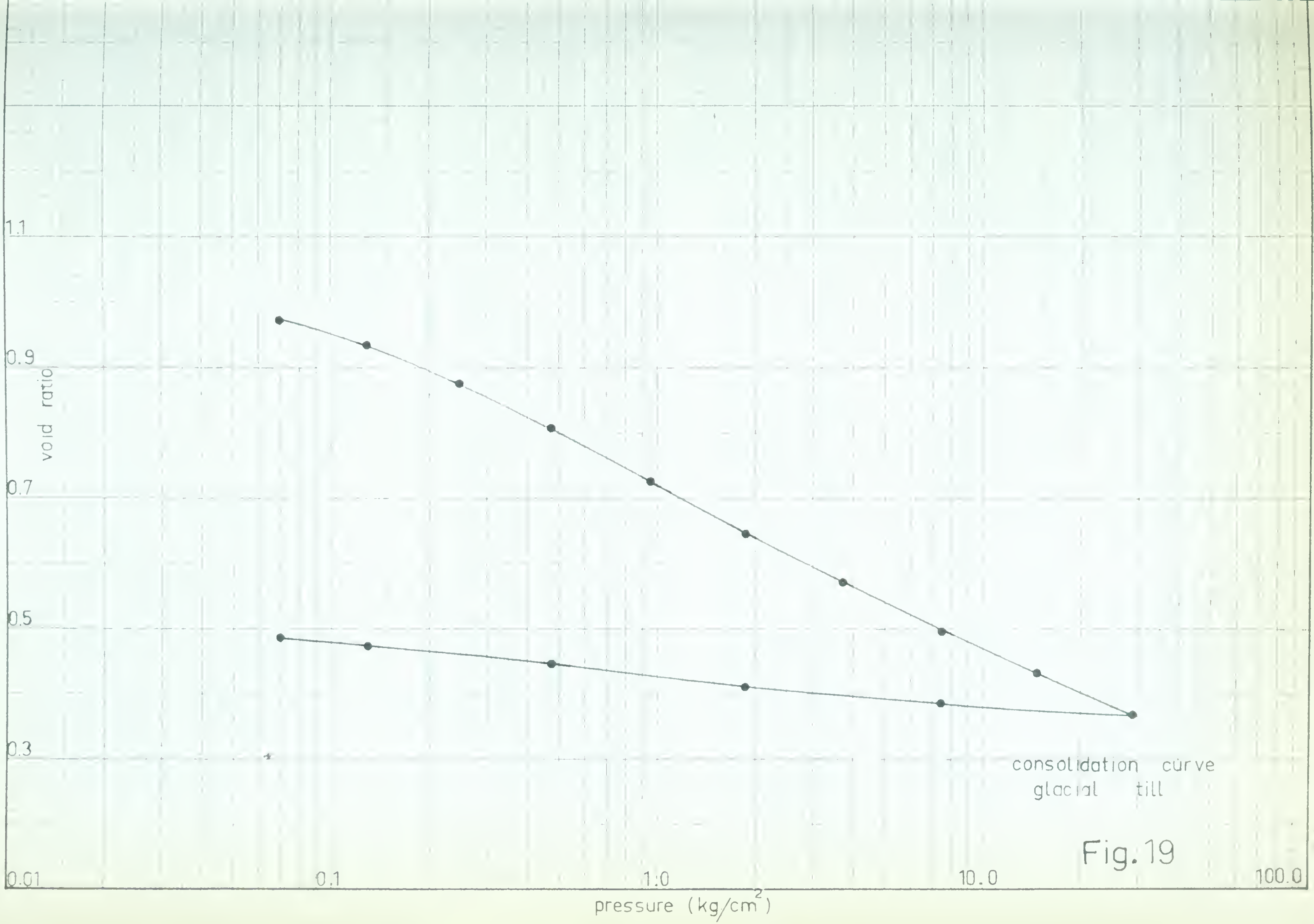

1.1
0.9
0.7
0.5
0.3
void ratio
0.01
0.1
1.0
10.0
100.0
pressure (kg/cm²)
consolidation curve
glacial till

Fig. 19

consolidation test. This test was run on the same soil as that used for the triaxial tests and was remoulded from the same initial moisture content.

Time permitted only one such test to be run on the Edmonton till and it was performed at room temperature. Unfortunately the temperature recorder was out of order when the test was run so that no record of temperature could be made.

The void ratio versus logarithm of pressure plot is shown on Figure 19. All compression versus time curves supporting this plot are on file with the Department of Civil Engineering.

A best fitting line was visually fitted to the plotted points, Figure 18. It can be seen that this curve is approximately parallel to the virgin compression curve for the one-dimensional consolidation test at room temperature. As for the case with the C H Edmonton clay, there is no particular trend evident which may be directly charged to the effects of temperature.

Three-dimensional consolidation.

Figures 20 to 24 inclusive are the results of triaxial compression achieved for the period preceding the shearing portion of the tests. As for the test series on the C H Edmonton clay, the curves have been reduced to a common datum at time equals 6 seconds after application of the confining pressure. Times for theoretical 100% consolidation

TABLE 12

SUMMARY OF THREE-DIMENSIONAL CONSOLIDATION FOR TRIAXIAL TESTS ON EDMONTON TILL

No.	Confining pressure kg/cm^2	Time for theoretical 100% consolidation min.	Water expelled cm^3	Temperature* ^oF		
				High	Average	Low
1-35T	1.5	280	8.91	36.4	35.7	33.4
2-35T	2.25	210	7.54	37.0	36.2	33.5
3-35T	4.0	140	9.56	37.6	36.9	34.0
4-35T	5.5	185	11.15	37.3	36.8	33.5
5-35T	6.25	150	11.16	37.5	36.7	32.2
1-75T	1.5	210	7.41	76.9	76.2	75.7
2-75T	2.25	115	7.65	79.7	77.3	76.0
3-75T	4.0	105	10.61	81.1	78.1	76.1
4-75T	5.5	76	11.84	77.8	77.2	76.8
5-75T	6.25	100	12.05	78.0	77.4	76.9

*Temperatures are for the period of consolidation.

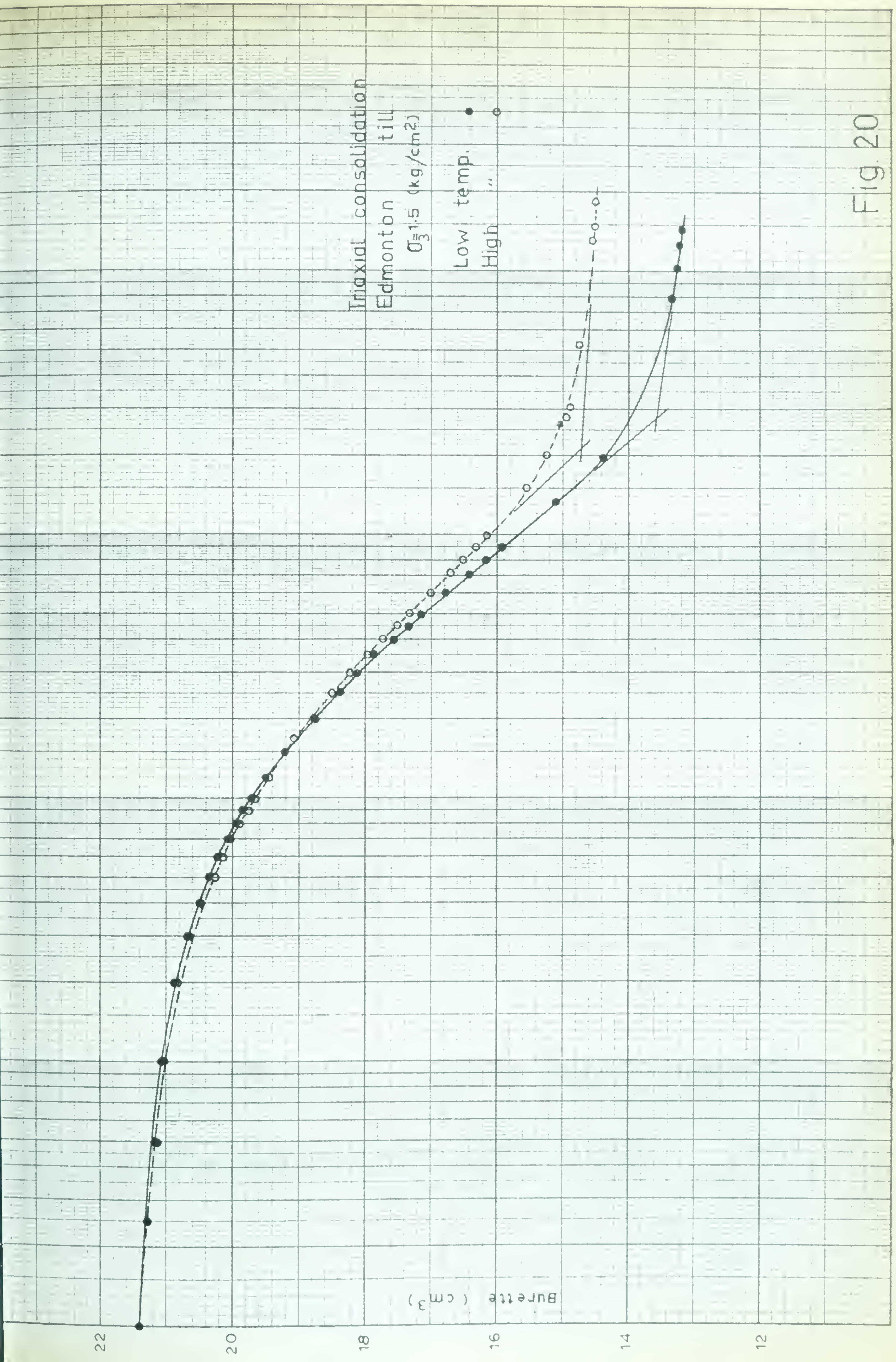

Triaxial consolidation
Edmonton till
σ_3=1.5 (kg/cm²)
Low temp. ●
High " ○
Time (min)
0.1
1.0
10
100
1000
Burette (cm³)
22
20
18
16
14
12

Fig. 20

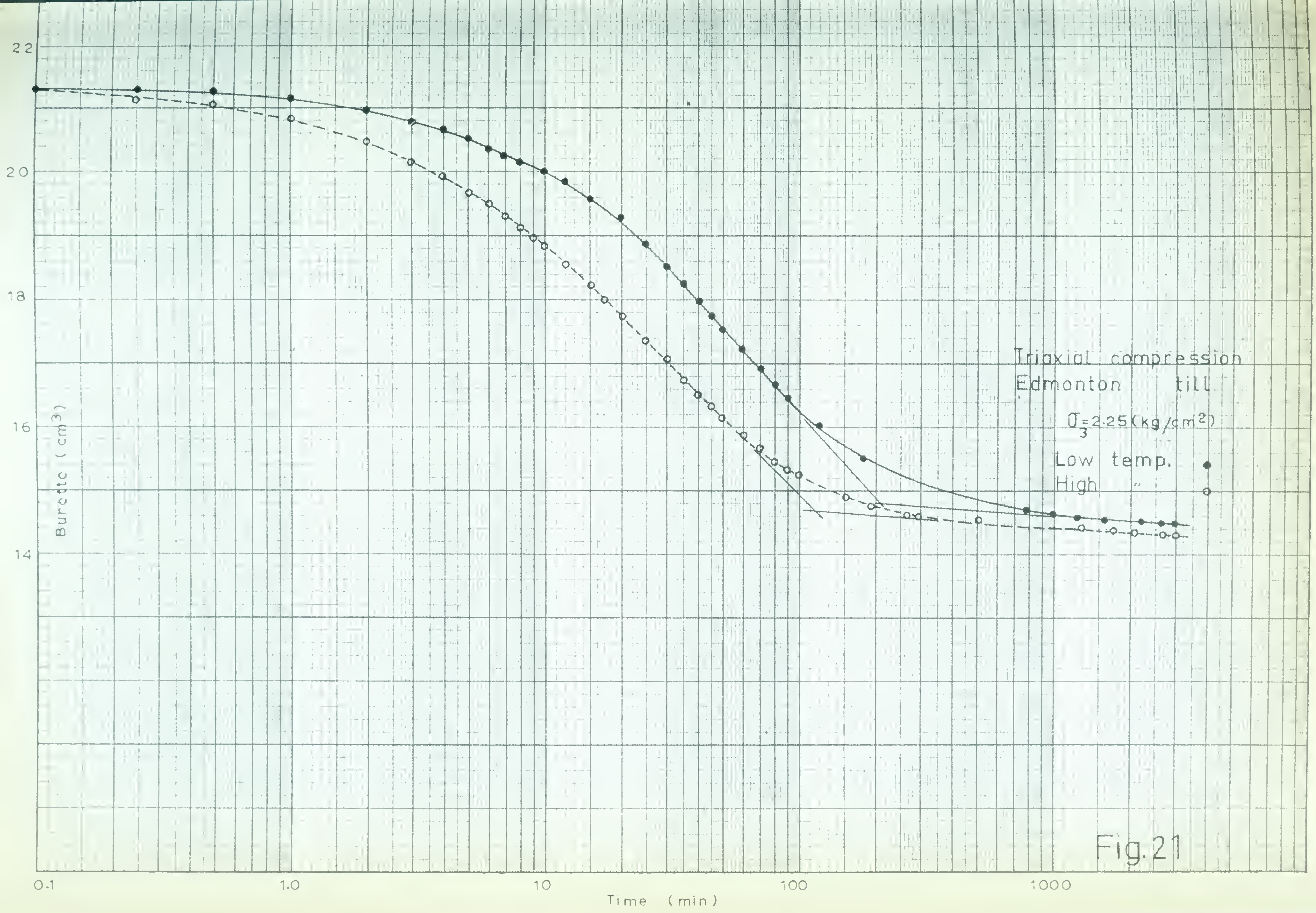

Triaxial compression
Edmonton till
σ_3=2·25(kg/cm^2)
Low temp. ●
High " ○
Burette (cm^3)
22
20
18
16
14
0.1
1.0
10
100
1000
Time (min)

Fig.21

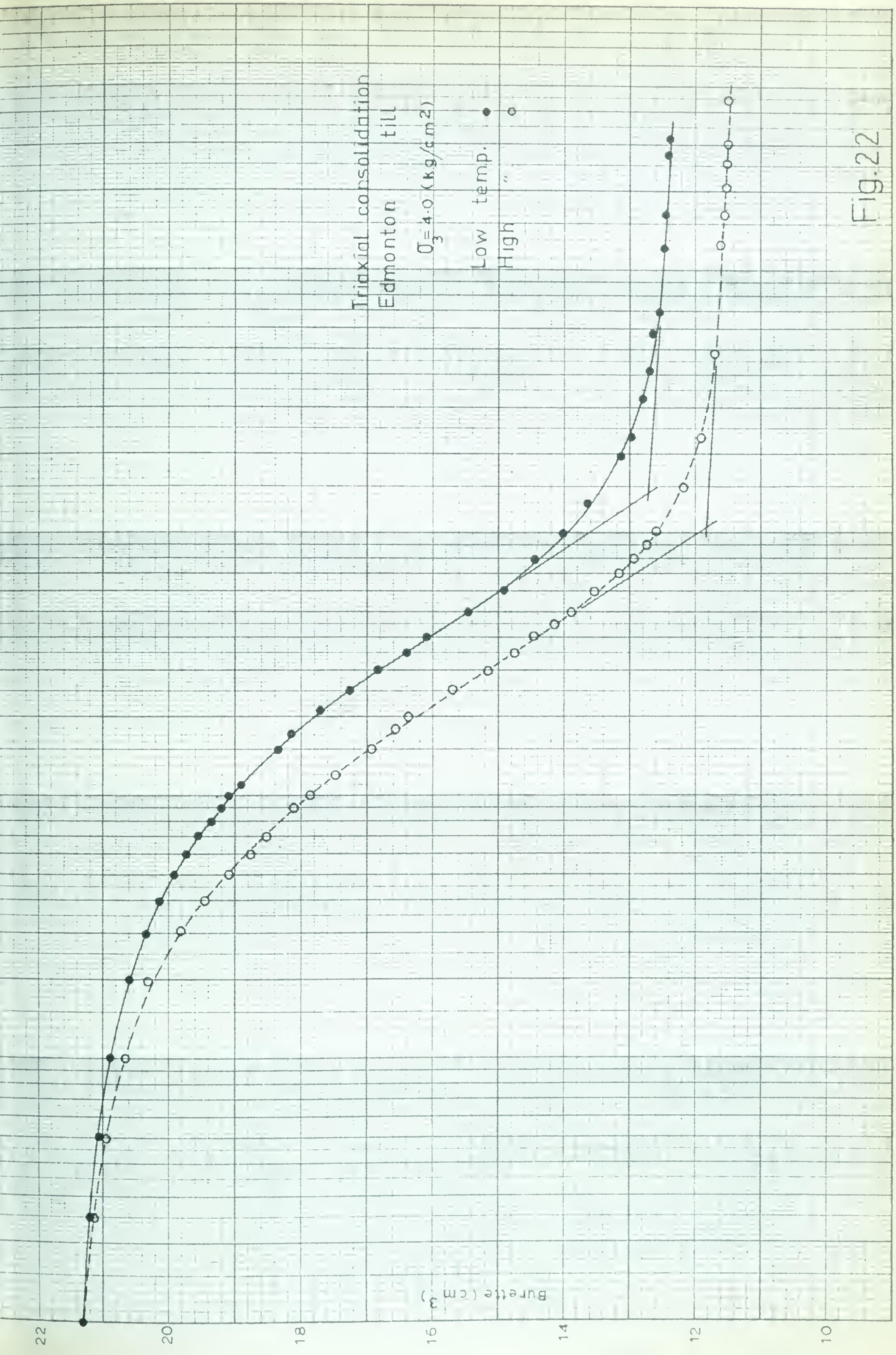

Triaxial consolidation
Edmonton till
$\sigma_3 = 4.0$ (kg/cm2)
Low temp. ●
High " ○
Time (min)
Burette (cm ^{3})
0.1
1.0
10
100
1000
22
20
18
16
14
12
10

Fig.22

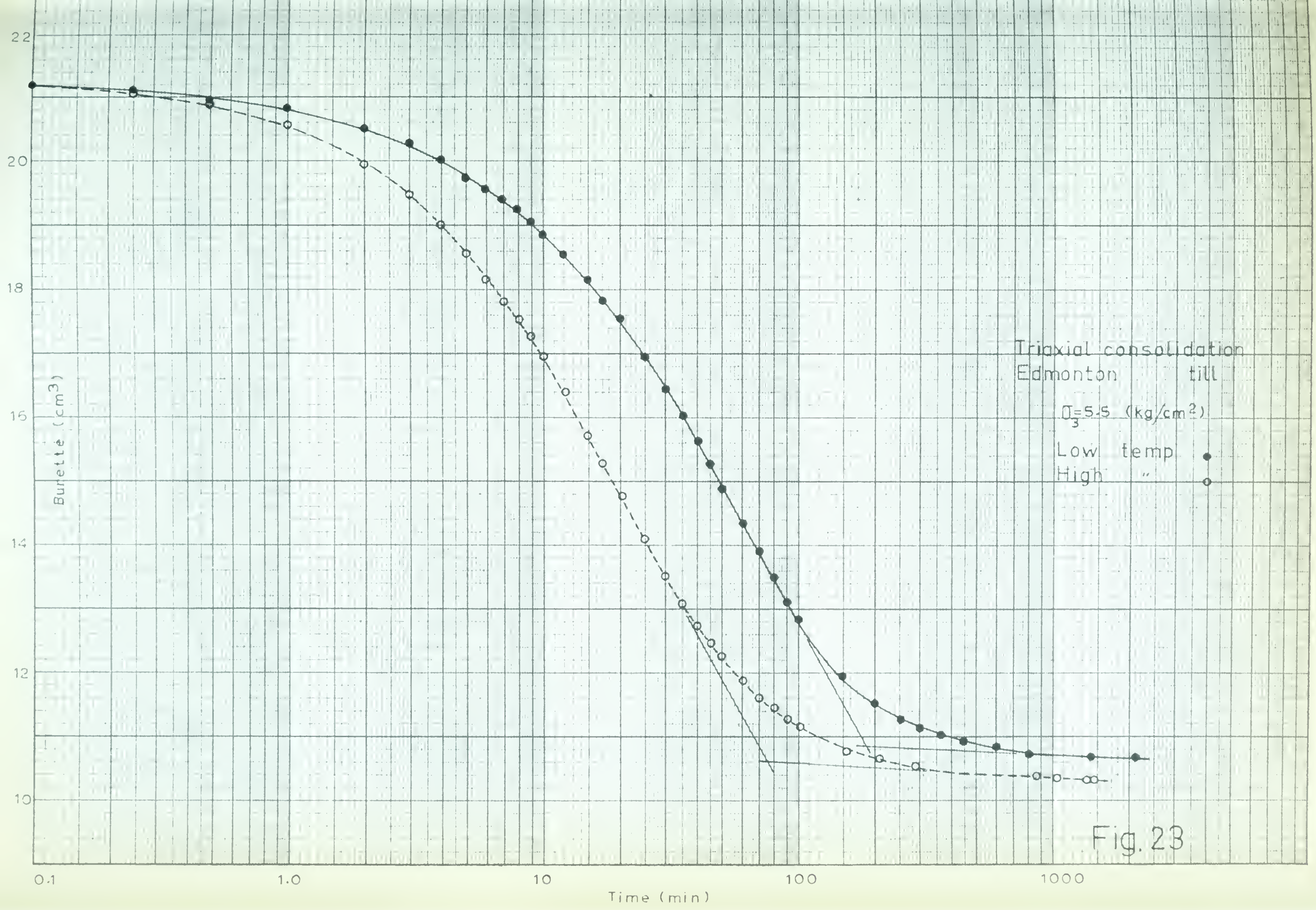

Triaxial consolidation
Edmonton till
σ_3=5.5 (kg/cm^2)
Low temp ●
High " ○
Burette (cm^3)
22
20
18
16
14
12
10
0.1
1.0
10
100
1000
Time (min)

Fig. 23

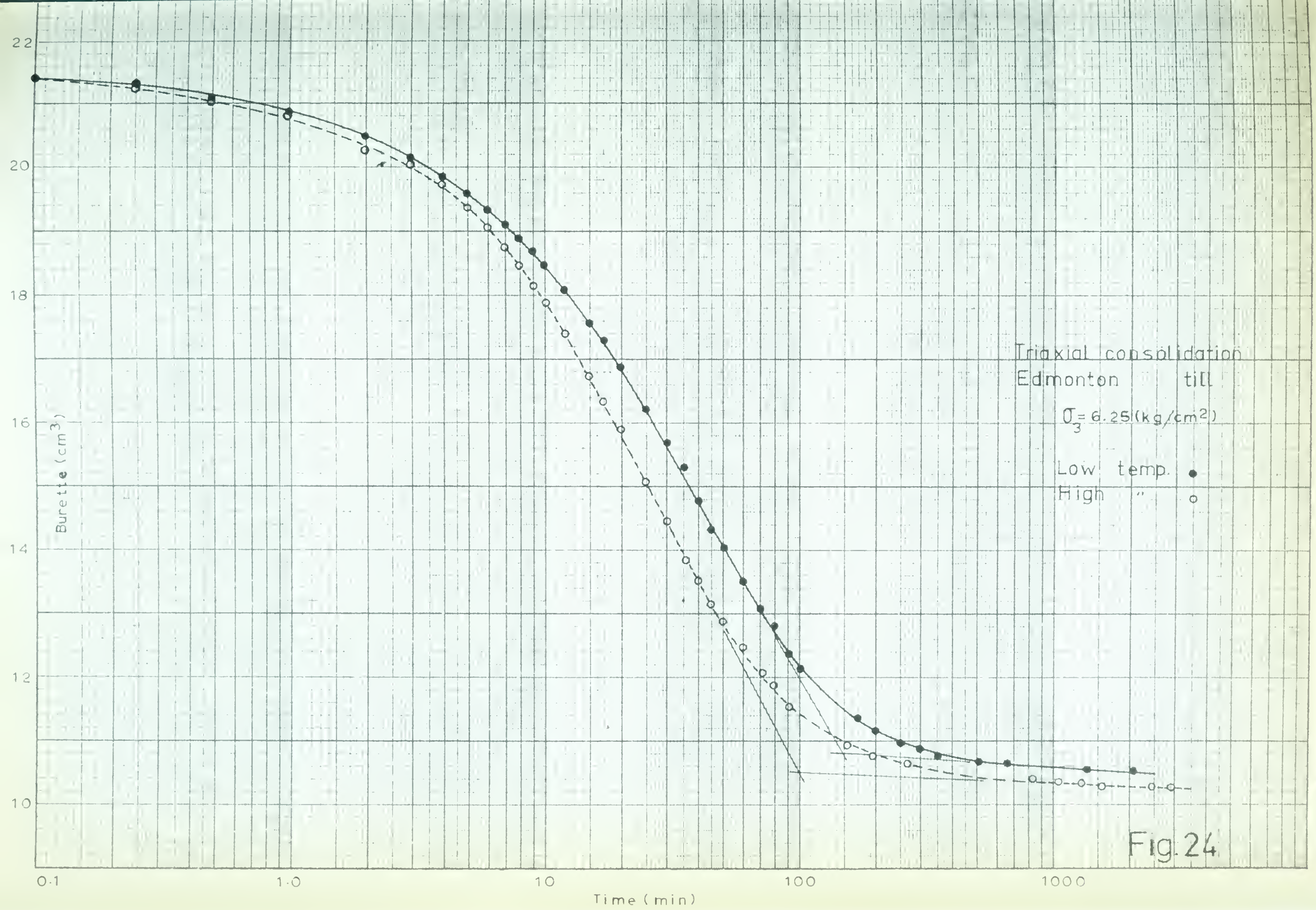

Triaxial consolidation
Edmonton till
$\sigma_3 = 6.25 (kg/cm^2)$
Low temp. ●
High " ○
Burette (cm^3)
22
20
18
16
14
12
10
0.1
1.0
10
100
1000
Time (min)

Fig. 24

and the amounts of water expelled are summarized in Table 12. These curves served as the criterion for the establishment of secondary compression. They were established by observations of expelled water and are thus subject to the same shortcomings as discussed for the series on the highly plastic clay.

Except for the test at a confining pressure of 1.5 kg/cm^2, Figure 20, the time curves exhibit the same general trends as for the consolidation of the C H Edmonton clay. That is the rate of compression is initially smaller for the case at low temperature, followed by a rapid increase up to about the time for theoretical 100% consolidation. After secondary compression has been reached the trend for a steeper slope is evident for the test at a confining pressure of 1.5 kg/cm^2 only, Figure 20 and Table 9 (a), at the low temperature. It appears that there is a similarity in the time rate of consolidation, between the two soil types, with respect to variation in temperature, but that the increase in steepness of the secondary compression branch with a lowering of temperature but is peculial only to the highly plastic clay. The reason for the change in slope of the secondary compression branch cannot be ascertained from the experimental results obtained in this investigation.

As for the three-dimensional consolidation of the C H Edmonton clay the volume change, at a given confining pressure and for the same time interval, is sensibly the same for the case of tests at low and high temperatures. Hence the effect would not be expected to be large on the shear strength of the soil tested.

Pore Pressure Parameter $\bar{A}$

Since the pore pressure parameter $\bar{A}$ affects the available shearing strength for some conditions of loading of a soil, an attempt was made to see if the recorded $\bar{A}$ values correlate with change in temperature. Figure 24 (a) shows the values of $\bar{A}$ versus consolidation pressures for all of the triaxial tests performed. The Edmonton till exhibits higher $\bar{A}$ values for four of the five test lateral pressures, at the high temperature than at the low temperature. There also appears to be a general trend for $\bar{A}$ to increase with increasing consolidation pressures. It may be possible to explain this increase in $\bar{A}$ with increase in temperature as being due to viscosity. That is if the temperature is lowered the viscosity increases and the tendency for the soil skeleton to reduce in volume due to shear strains, is reduced and hence the induced pore pressure is less resulting than in a lower $\bar{A}$. A possible explanation for an increase in $\bar{A}$ with increasing consolidation pressures may lie in the fact that the specimens may not be fully saturated, in which case B, in the expression $B - A = \bar{A}$ would be less than unity. Hence if the consolidation pressure increases then B may also increase and so too will $\bar{A}$.

For the C H clay, at three of the five consolidation pressures, $\bar{A}$ was found to be greater at the low temperature than at the high temperature, which is opposite for the trend observed for the Edmonton till. The values determined by Thomson (42) are also shown on Figure 24 (a) and it can be seen that these $\bar{A}$ values overlap the data obtained by the writer. Therefore, it appears that if there is any trend for $\bar{A}$ to vary with temperature, this may be masked by uncontrollable operator errors.

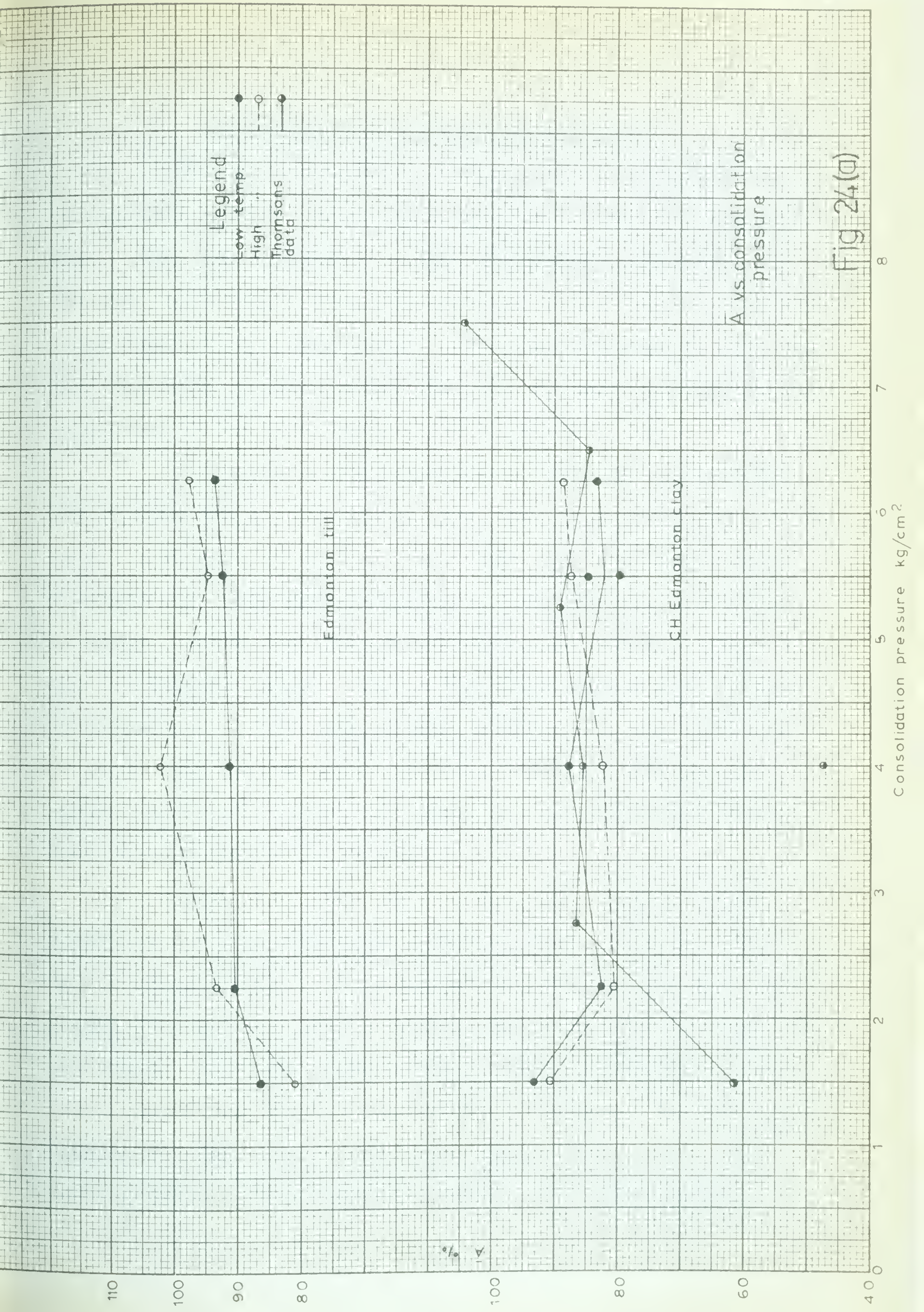


Fig 24(a)

Ā vs consolidation pressure

One-Dimensional Consolidation Tests

Due to limitations of time only two standard one-dimensional consolidation tests were run on the C H Edmonton clay. One test was run at a low temperature comparable to the low temperature triaxial compression test series, and the other test at room temperature. The low temperature test was run in a walk-in freezer and the test at room temperature was performed in the room immediately adjacent to it.

A record of the temperatures holding in the water surrounding the consolidating specimen was kept for the entire test. A summary of the average, high, and low temperatures obtained for each load increment has already been presented in Table 7 under the section of results of triaxial tests on the C H Edmonton clay. All of the strip charts and listings of temperatures have been placed on file with the Department of Civil Engineering under separate binding. The pressure versus void ratio plots, for these two consolidation tests, have been presented in Figure 7.

Figures 25, 26, and 27, are dial reading versus logarithm of time curves for loads of 0.95, 7.49, and 29.91 kg/cm^2 respectively. These curves are typical and have been chosen to represent a low, medium, and high load increment in the tests. All other dial reading versus logarithm of time curves have been filed under separate binding. The curves of Figures 25, 26, and 27, have been reduced to a common dial reading datum at time equals 6 seconds for illustrative

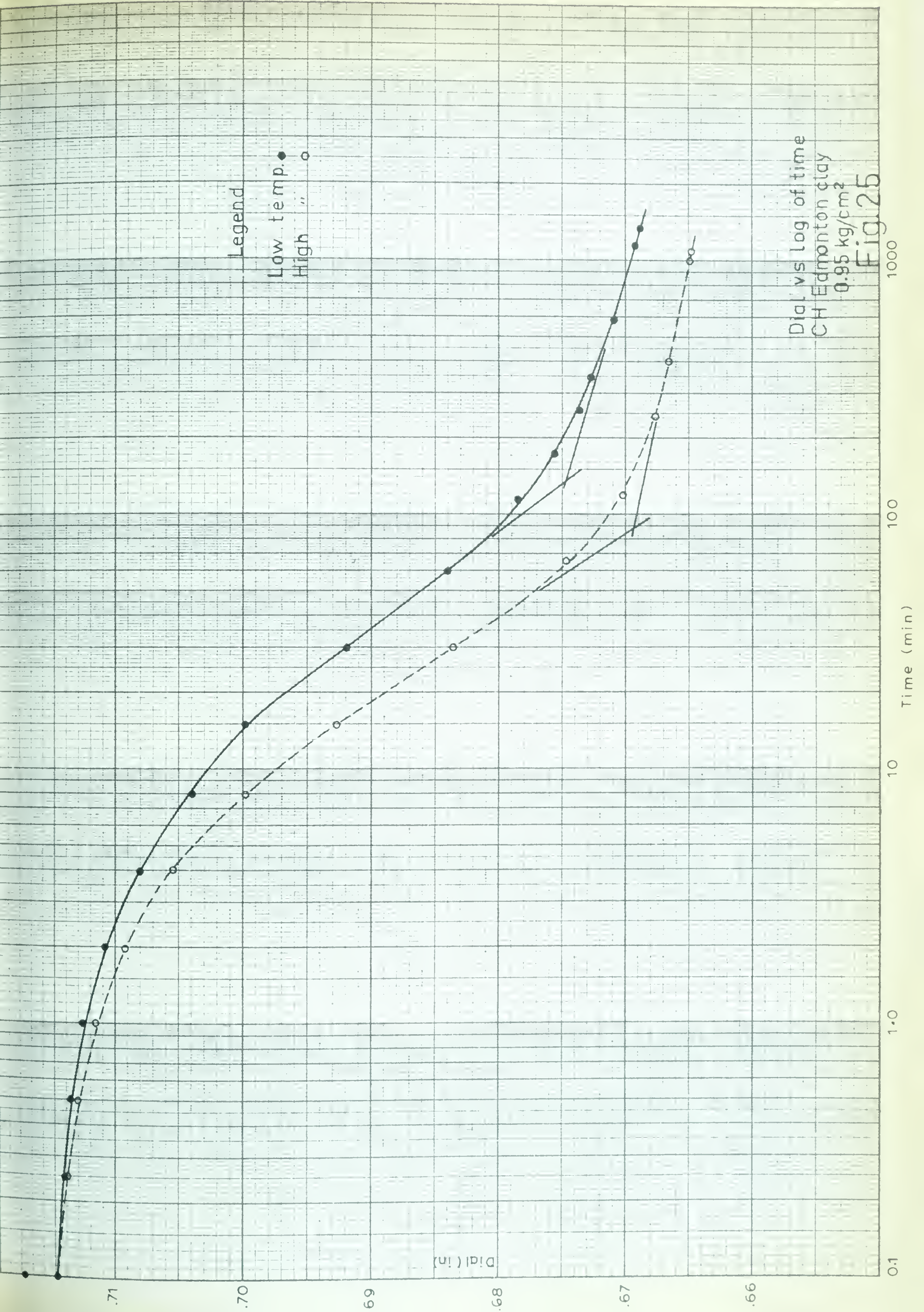
TABLE 13

TIMES FOR THEORETICAL 100% CONSOLIDATION FOR ONE-DIMENSIONAL CONSOLIDATION ON C H EDMONTON CLAY

Low temperature test					High temperature test				
Load kg/cm^2	*temperature ^oF			$**t_{100}$ min.	Load kg/cm^2	temperature ^oF			t_{100} min.
	High	Average	Low			High	Average	Low	
0.07	34.1	33.7	33.5	210	0.07	77.9	76.3	75.8	160
0.13	35.0	33.6	33.3	200	0.13	76.4	76.2	75.7	130
0.25	34.1	33.8	33.5	200	0.25	76.7	76.2	75.8	93
0.48	-	-	-	170	0.48	-	-	-	130
0.95	-	-	-	135	0.95	-	-	-	88
1.88	34.3	34.1	34.0	135	1.88	-	-	-	96
0.48	34.6	34.3	33.8	rebound	0.48	77.2	76.4	76.1	rebound
0.13	34.7	34.2	34.1	rebound	0.13	77.5	77.0	76.7	rebound
0.07	35.0	34.1	33.3	rebound	0.07	77.9	77.4	76.2	rebound
0.13	35.3	34.9	34.1	not clearly defined	0.13	77.2	77.0	75.6	not clearly defined
0.25	35.8	35.0	34.8		0.25	77.2	77.2	77.2	
0.48	35.1	34.6	34.1	92	0.48	77.7	77.1	76.7	60
0.95	34.3	33.6	33.4	50	0.95	76.9	76.5	76.2	23
1.88	34.6	33.5	33.1	60	1.88	77.2	76.6	75.8	90
3.75	35.9	33.6	33.3	170	3.75	76.4	75.9	75.2	100
7.49	33.8	33.6	33.1	140	7.49	76.0	75.3	74.7	75
14.96	34.0	33.8	33.6	150	14.96	76.2	75.3	74.7	84
29.91	33.8	33.6	33.5	160	29.91	75.7	75.4	75.2	98

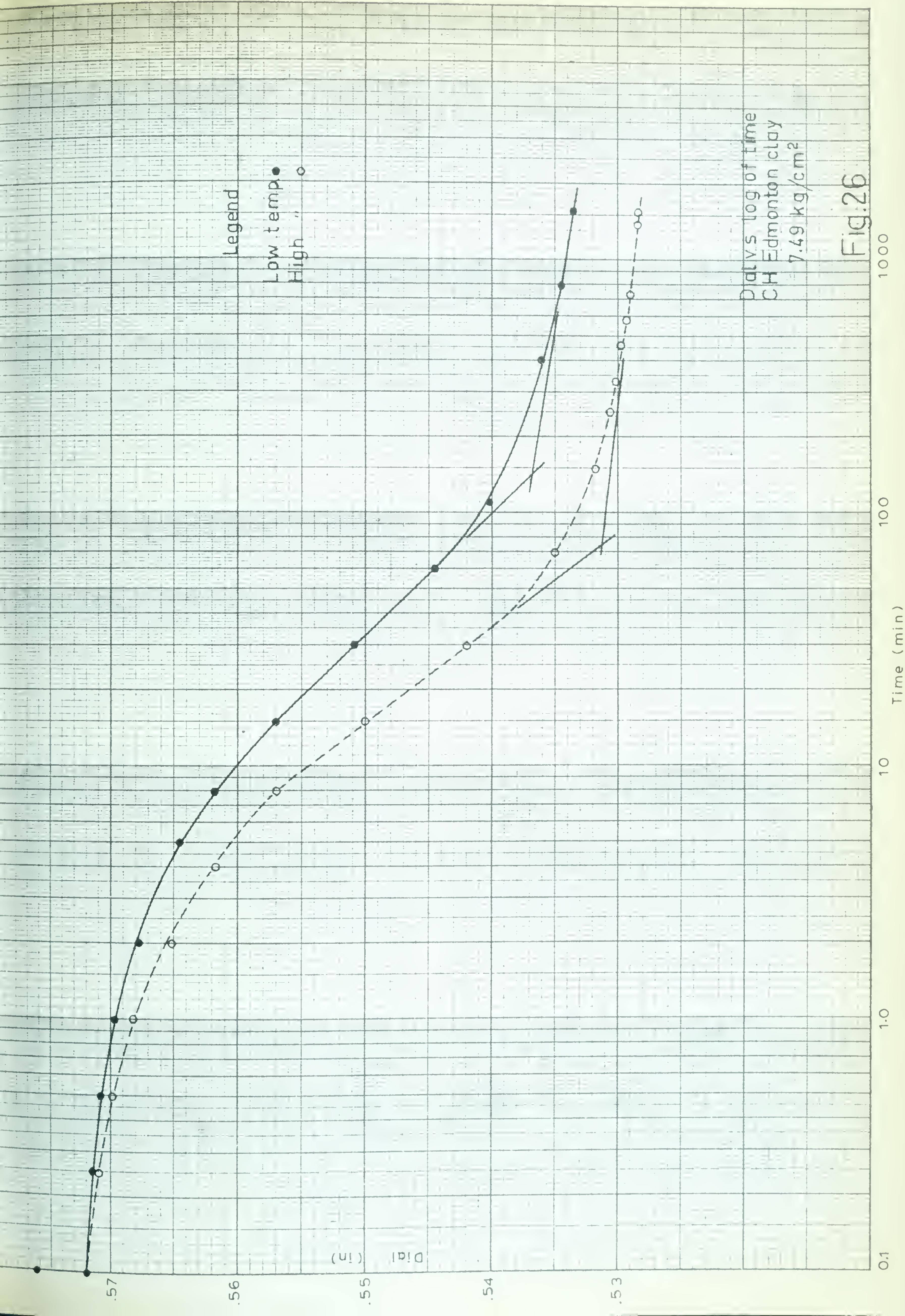
*temperature is that holding in water surrounding specimen

$**t_{100}$ = time for theoretical 100% consolidation



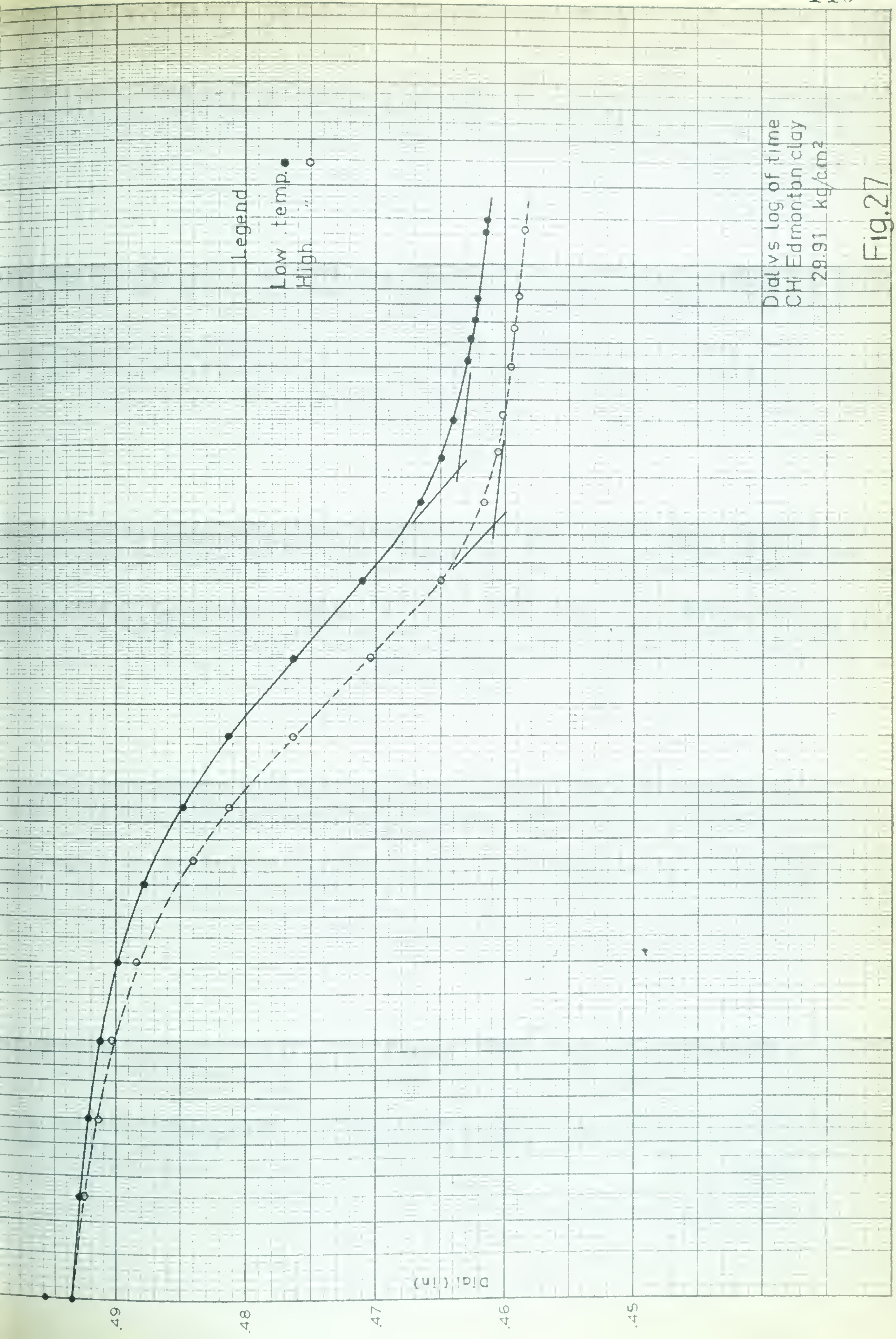
Dial vs log of time
CH Edmonton clay
0.95 kg/cm²

Fig. 25



Dial v.s log of time
CH Edmonton clay
7.49 kg/cm²

Fig.26



Dial vs log of time
CH Edmonton clay
29.91 kg/cm²

Fig.27

purposes. These curves clearly illustrate that the rate of consolidation is markedly affected by changes in temperature. Table 13 summarizes the times for theoretical 100% consolidation for the two tests run.

It is noted that the total amount of compression, for a given load increment and for approximately the same time interval, is larger for the case of tests run at room temperature. This is the reason for the relative displacement of the void ratio versus logarithm of pressure plots, Figure 7, presented earlier under the section of triaxial test results on the C H Edmonton clay. However, the compressive index remains essentially the same for tests at both temperatures. As for the three-dimensional consolidation tests the slopes of the secondary compression branches, of the compression versus logarithm of time plots, are steeper for the test at the low temperature.

Gray (13) has determined that temperature variations have a fundamental effect on the secondary portion of the compression versus logarithm of time plots. By running tests on the same material at different temperatures it was found that the secondary compression branch of the empirical plot, was generally steeper for the tests conducted at the high temperatures. This is directly opposite to the trends found in both the one-dimensional and three-dimensional consolidation results of this investigation. However, for both the one-dimensional consolidation test results of this investigation and the work

reported by Gray, it was found that the virgin compression branches of the e log P plots at the high temperature were displaced to the left relative to that for the low temperature. The slopes of the virgin compression branches remain essentially the same. Finn (10) also reports the results of consolidation tests at varying temperatures. From this work he concluded that the amount of compression for a given load increment was independent of temperature but that estimates of the rate of consolidation, using Terzaghis one-dimensional consolidation theory, could be affected by temperature. The coefficient of consolidation was found not to vary appreciably with temperature in the range 70°F to 80°F, but varied enough in the range of 40°F to 70°F, to be worthy of inclusion in a settlement analysis. He has suggested a correction to be applied to the coefficient of consolidation based on the change in viscosity of water due to temperature change. It is given by the following expression:

$$\frac{C_{vt_1}}{C_{vt_2}} = \frac{U_{t_2}}{U_{t_1}},$$

Where:

C_{vt_1} is the coefficient of consolidation at temperature t_1

C_{vt_2} is the coefficient of consolidation at temperature t_2

U_{t_1} and U_{t_2} are the coefficients of viscosity at temperatures t_1 and t_2 respectively

Time did not permit the study of the effect of temperature on the consolidation characteristics of the Edmonton till soil. Only one consolidation test was run at room temperature, to permit the determination of the virgin compression branch for comparison with the moisture content versus logarithm of compressive strength tests in the triaxial test series. A record of the temperatures holding in this test is also not presented, as the temperature recorder failed during this test.

It is interesting to speculate as to the reasons for the observed time lags and increased steepness of the secondary compression branches for both one-dimensional and three-dimensional consolidation at the reduced temperature. For the case of primary compression, attributable to the expulsion of free pore water, under the imposed increment of external load, the time lag can be charged to a decrease in permeability. This is due to an increase in viscosity of the water because of the low temperature. However, this does not satisfactorily explain the reason for the increase in steepness observed in the secondary compression branch at the low temperature. Lambe (21) on the basis of colloidal chemistry suggests that the diffuse double layer will expand with a decrease in temperature. Furthermore because of a reduction

in thermal energy of cations in the double layer water surrounding the clay particles, it may well be that the water is better oriented, Low and Lovell (26). While there is as yet no general agreement on the precise nature of the organization of such water molecules, it is generally agreed that the water adsorbed on the clay mineral surfaces and for some distance outward is not in the state of liquid water, but has some organization in which the water molecules are held together by hydrogen bonding, Grim (34) (35), Rodebush and Buswell (30). In the light of this concept it is conceivable that an actual reduction in pore space may take place at reduced temperature and hence contribute to the observed time lag in consolidation.

A possible mechanism of secondary compression effects in saturated clays has been postulated by Lambe (20) and is as follows:

> 'Even after the excess hydrostatic pressures in the pore water are dissipated the particles continue to approach each other. During this very slow process the adsorbed water is extruded from between the particles and to some extent becomes pore water. While this process can occur with negligible volume change, the extrusion or diffusion of adsorbed water may require many years to be completed.'

It is not unreasonable to assume that under sustained load there could be a break-down in the structure of the water in the outermost fringes of the double layer. Hence due to a relatively thicker oriented water structure at the low temperature the break-down in structure is greater and is reflected in a steeper slope of the secondary compression branch than at

the high temperature. It is tacitly implied that there is a gradual transfer of stress from the soil skeleton and the rigid water onto the free water formed, and that the excess hydrostatic pressure so created drives out the water. Credulity of such an assumption is enhanced by the fact that the volume change, in the case of the three-dimensional consolidation, has been measured by expelled water.

It must be emphasized that the reasoning presented in the paragraphs above must be considered as purely academic. It has been presented in an effort to at least qualitatively explain observed phenomena and is limited to the two soil types investigated.

CHAPTER VI

CONCLUSIONS

The results of a laboratory testing programme, consisting essentially of consolidated undrained triaxial compression tests with pore pressure measurements, have been presented. The tests were carried out on remoulded samples of two Edmonton clays. From the results it can be concluded that:

1. For the two soil types investigated, a clay of high plasticity and a silty clay of low plasticity, the effect of temperature variation on the angle of shearing resistance in terms of total or effective stress, is of no practical significance.

2. For the temperatures investigated there is an appreciable change in cohesion with variation in temperature. The values of cohesion are larger for the tests at room temperature than for the tests at a temperature just above freezing and this increase in cohesion appears to be larger for the silty clay.

3. For the soils studied, the consolidation versus logarithm of time curves exhibit the same general characteristics for both three-dimensional and one-dimensional consolidation.

4. The time rate of consolidation is influenced by a

lowering of temperature in that the time to theoretical one hundred per cent consolidation is greater for the low temperature than at the high temperature. For the Edmonton till the average increase is 70% and for the C H Edmonton clay the average increase is 40%.

5. Although the time rate of consolidation can be significantly affected by temperature variation, the total amount of consolidation remains sensibly the same, for the two soils tested at a given confining pressure in the temperature range investigated.

6. The secondary compression branches of the consolidation versus logarithm of time curves, for both one and three-dimensional consolidation, are steeper at the low temperature than at the high temperature investigated, for the highly plastic clay but are sensibly the same for the silty clay.

7. The apparatus developed, for cooling the specimen in the triaxial cell, is satisfactory in principle.

8. More refinement in the temperature control mechanism is necessary, in order to reduce variations in temperature during a test.

9. The variation of temperature in the central portion of a triaxial cell, if moderately insulated, is relatively small when the tests are conducted at room temperature.

CHAPTER VII

RECOMMENDATIONS

On the basis of experience with this triaxial testing programme the writer recommends that the following points be considered:

1. It is recommended that no further triaxial testing be undertaken to determine temperature effects since it has been shown that the effect of temperature, on soils ranging from low clay mineral content to high clay mineral content, is of no practical significance on the angle of shearing resistance.

2. It is felt that more uniform initial specimen conditions can be achieved. It is therefore recommended that a sedimentation procedure, similar to that adopted by Olson and Mitranovas (28), be considered in general triaxial testing programmes using remoulded samples. Alternatively the mechanical extruder briefly described by Schmertmann and Osterberg (37) should be investigated as it appears that this method, in addition to convenience, allows for a large number of specimens to be prepared with identical initial conditions.

3. The results of three-dimensional consolidation within the triaxial test cells can provide very useful information in the study of consolidation characteristics. However, it is felt that the reliability of the test results can be improved. It is suggested that research be directed

into devising some means of observing axial consolidation with time in addition to the usual means of observing volume change by burette readings.

4. The apparatus constructed has proved successful in all phases with the exception of the temperature control mechanism. If any future testing be contemplated using the design outlined in this investigation it is recommended that further refinement to the temperature control mechanism be undertaken.

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APPENDIX I

Representative Triaxial Test Data Sheets and Sample Calculations

The data sheets and sample calculations which follow are for triaxial test No. 4-75 on the C H Edmonton clay for a confining pressure of 5.5 kg/cm^2. These data sheets are typical for all the triaxial tests performed in this investigation. The consolidation data sheet is the record of three-dimensional consolidation prior to shearing of the specimen. The initial dimensions of the specimen and initial moisture content, determined from sample trimmings, was also shown thereon. From this consolidation record a plot of burette reading versus logarithm of time was constructed, Figure 28.

The triaxial compression data sheet is the form of the data sheets kept for the compression portion of the test. The various quantities shown on this data sheet were arrived at using the following relations:

Per cent axial strain

$$\% \text{ strain} = \frac{\text{change in length}}{\text{original length}}$$

Corrected area (A_c)

$$A_c = \frac{A_o}{1 - \mu}$$

where A_o = original cross sectional area

μ = axial strain as a decimal

Deviator Stress

$$\sigma_1 - \sigma_3 = \frac{k \delta K}{A_c}$$

where k = load per stress dial division, from proving ring calibration chart

δ = the number of stress dial divisions

K = an area correction factor, Figure 29

A_c = corrected area, assuming no volume change

The major principal effective stress was obtained from a knowledge of the deviator stress, the induced pore pressure, and the confining pressure. The minor principal effective stress was taken as the difference between the confining pressure and the pore pressure. The principal effective stress ratio was computed from a knowledge of the above two principal effective stresses.

A running record of deviator stress, pore pressure, major and minor principal effective stress, and principal effective stress ratio, versus per cent axial strain was kept up as the test progressed, Figure 30.

NIVERSITY OF ALBERTA	Project	Thesis
EP'T. OF CIVIL ENGINEERING	Sample No.	17
OIL MECHANICS LABORATORY	Test No.	4-75
ONSOLIDATION DATA FOR RIAXIAL COMPRESSION TEST	Engineer	W.S.
	Technician	W.S.
mple Description: Remoulded ghly plastic Edmonton clay.	Date set-up	19/2/62

Wet wt. & tare	138.5642
tare	2.2803
Wet wt. start	136.2839

ecimen Dimensions:

		1.	2.	Ave:
ngth mm.		80.74	80.68	80.71
am. mm.	Top	35.90	36.00	35.95
	Centre	35.66	35.80	35.73
	Bottom	35.24	35.34	35.29

AREA

Top	A_t	1014.536 mm^2
Bottom	A_b	977.626 mm^2
Centre	A_c	1002.157 mm^2

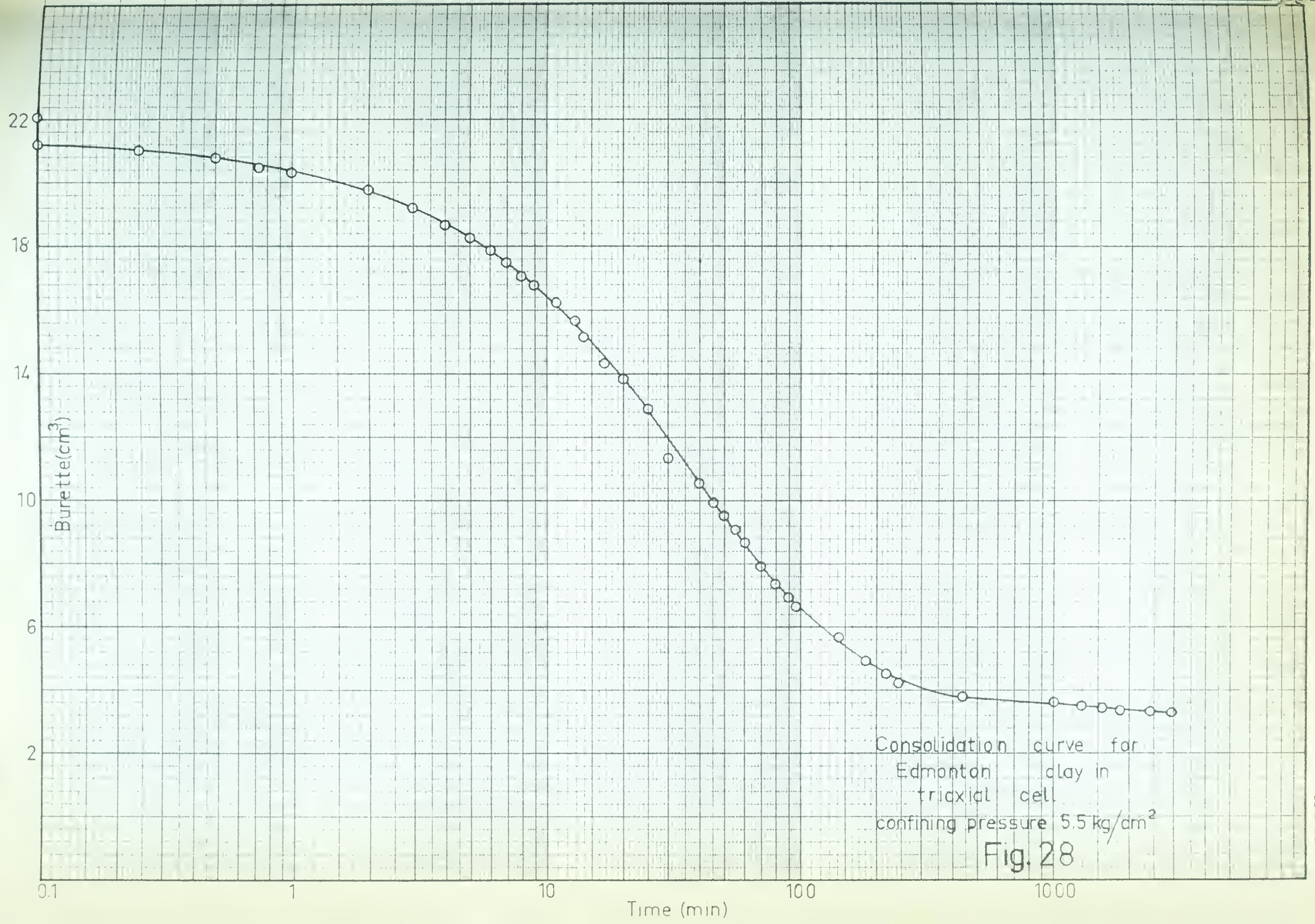
st lateral pressure: 5.5 Kg/cm^2

$A_o = 1/4(A_t + 2A_c + A_b)$
$= 999.119\ mm^2$

te & Time	△T Min.	Burette c.c.	Date & Time	△T Min.	Burette c.c.
/2/62	0.0	22.11		55	9.03
:33	0.1	21.20		60	8.63
	0.25	21.05		70	7.94
	0.50	20.75		80	7.39
	1	20.33		90	6.93
	2	19.79		95	6.68
	3	19.20		142	6.38
	4	18.65		182	4.83
	5	18.28		219	4.58
	6	17.89		244	4.13
	7	17.49		447	3.83
	8	17.08	21/2/62	1032	3.60
	9	17.00	8:45	1295	3.46
	11	16.23		1562	3.41
	13	15.63		1842	3.38
	14	15.22	22/2/62	2472	3.33
	17	14.28	8:45	2967	3.30
	20	13.92			
	25	12.88			
	30	11.23			
	40	10.55			
	45	9.95			
	50	9.48			

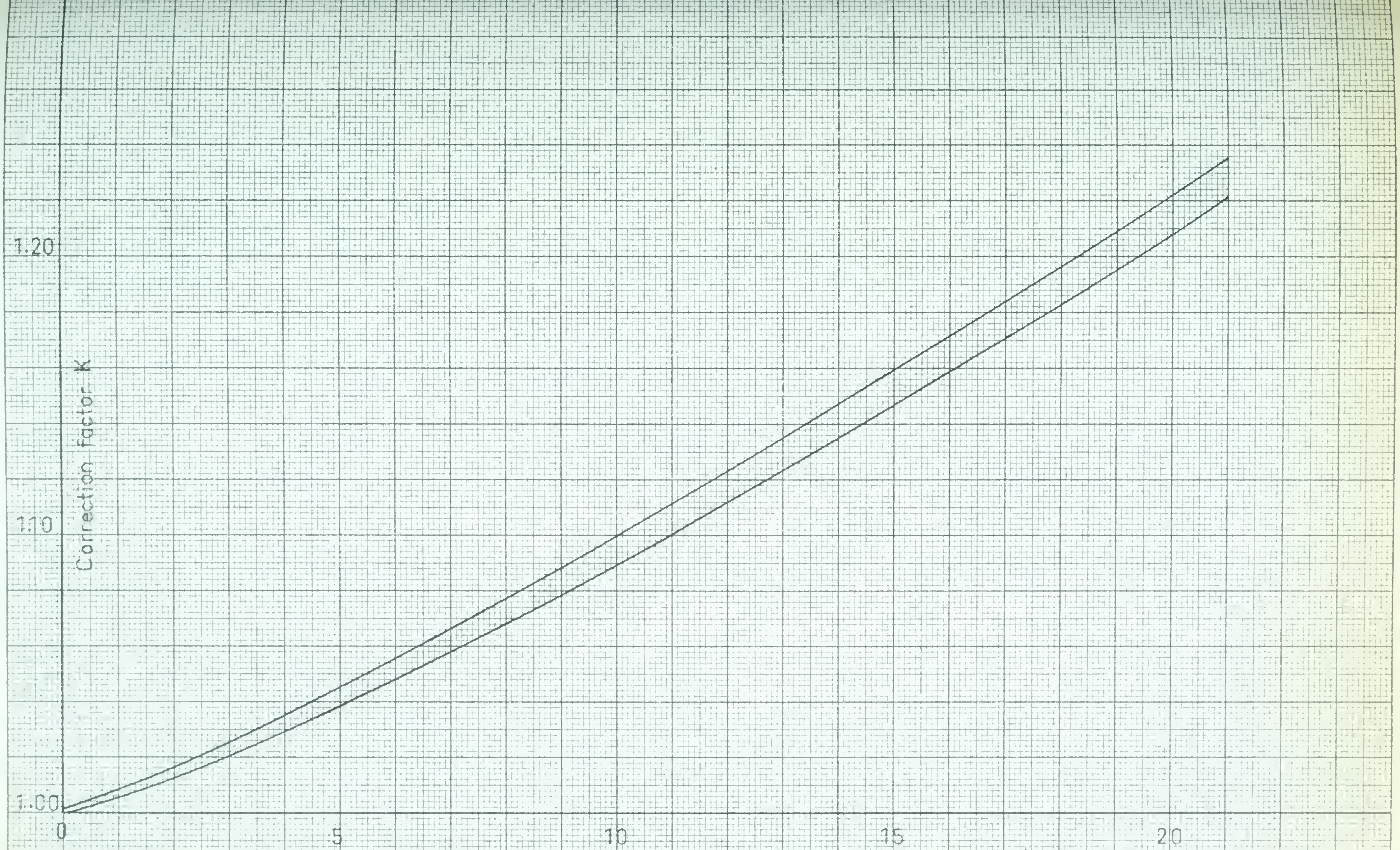
Moisture Content From Sample Trimmings:

Wet Wt & tare	97.7554
Dry Wt & tare	86.2048
Wt water	11.5506
Wt tare(S-31)	64.0272
Wt dry soil	22.1776
Moisture content	52.08%



Consolidation curve for Edmonton clay in triaxial cell confining pressure 5.5 kg/dm^2

Fig. 28



Area correction factor for consolidated undrained tests (after ref.27)

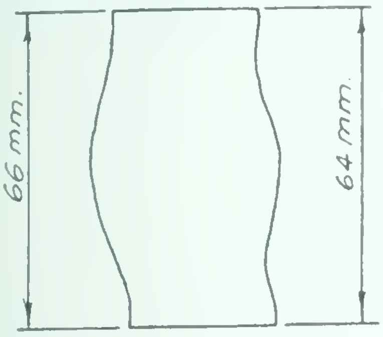
Fig.29

UNIVERSITY OF ALBERTA
DEP'T OF CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

TRIAXIAL COMPRESSION TEST

Project	Thesis
Sample No.	17
Test No.	4-75
Engineer	W.S.
Technician	W.S.
Date of test	23/2/62
Lateral pressure	5.5 kg/cm^2
Back pressure	2.0 kg/cm^2
Remarks	Proving ring No.3-1498

SKETCH AT FAILURE



Strain rate = 302.4 min/mm
= 2.25 % per hour.
Area correction factor K = 1.199

e	Strain Dial	A_c	Load Per Div.	Stress Dial	Deviator Stress	Pore Press.	Effective Stress		Stress Ratio	Axial Comp. Strain
n	Div.	cm2	Kg.	Div.	Kg/cm^2	Kg/cm^2	Maj.	Min.		%
2	8	10.00	4766	132	0.75	0.33	5.92	5.17	1.145	0.1
1	16	10.01	4605	215	1.19	0.57	6.12	4.93	1.241	0.2
8	24	10.02	4537	270	1.47	0.77	6.20	4.73	1.311	0.3
3	32	10.03	4491	313	1.68	0.93	6.25	4.57	1.368	0.4
8	40	10.04	4464	345	1.84	1.05	6.29	4.45	1.413	0.5
2	48	10.05	4443	371	1.97	1.15	6.32	4.35	1.453	0.6
6	56	10.06	4425	395	2.08	1.25	6.33	4.25	1.489	0.7
1	65	10.07	4410	417	2.19	1.35	6.34	4.15	1.528	0.8
4	73	10.08	4399	434	2.27	1.46	6.31	4.04	1.562	0.9
8	81	10.09	4389	449	2.34	1.55	6.29	3.95	1.592	1.0
2	89	10.01	4380	463	2.41	1.62	6.29	3.88	1.621	1.1
5	97	10.11	4374	474	2.46	1.66	6.30	3.84	1.641	1.2
9	105	10.12	4369	484	2.51	1.73	6.28	3.77	1.666	1.3
2	113	10.13	4364	494	2.55	1.79	6.26	3.71	1.687	1.4
5	121	10.14	4358	504	2.60	1.86	6.24	3.64	1.714	1.5
9	129	10.15	4352	513	2.64	1.93	6.21	3.57	1.739	1.6
2	137	10.16	4349	521	2.67	1.98	6.19	3.52	1.759	1.7
5	145	10.17	4345	529	2.71	2.03	6.18	3.47	1.781	1.8
9	153	10.18	4340	537	2.74	2.07	6.17	3.43	1.799	1.9
2	161	10.19	4338	545	2.78	2.11	6.17	3.39	1.820	2.0
0	182	10.22	4329	562	2.85	2.20	6.15	3.30	1.864	2.25
7	202	10.25	4322	577	2.92	2.30	6.12	3.20	1.913	2.5
5	222	10.27	4318	591	2.98	2.37	6.11	3.13	1.952	2.75
2	242	10.30	4310	603	3.03	2.43	6.10	3.07	1.987	3.0
9	262	10.33	4308	614	3.07	2.49	6.08	3.01	2.020	3.25
6	282	10.35	4303	624	3.11	2.54	6.07	2.96	2.051	3.5
4	303	10.38	4300	633	3.14	2.60	6.04	2.90	2.083	3.75
1	323	10.41	4280	642	3.16	2.64	6.02	2.86	2.105	4.0
5	363	10.46	4290	660	3.25	2.73	6.02	2.77	2.173	4.5
9	404	10.52	4286	676	3.30	2.81	5.99	2.69	2.227	5.0
4	444	10.52	4280	690	3.35	2.85	6.00	2.65	2.264	5.5

UNIVERSITY OF ALBERTA
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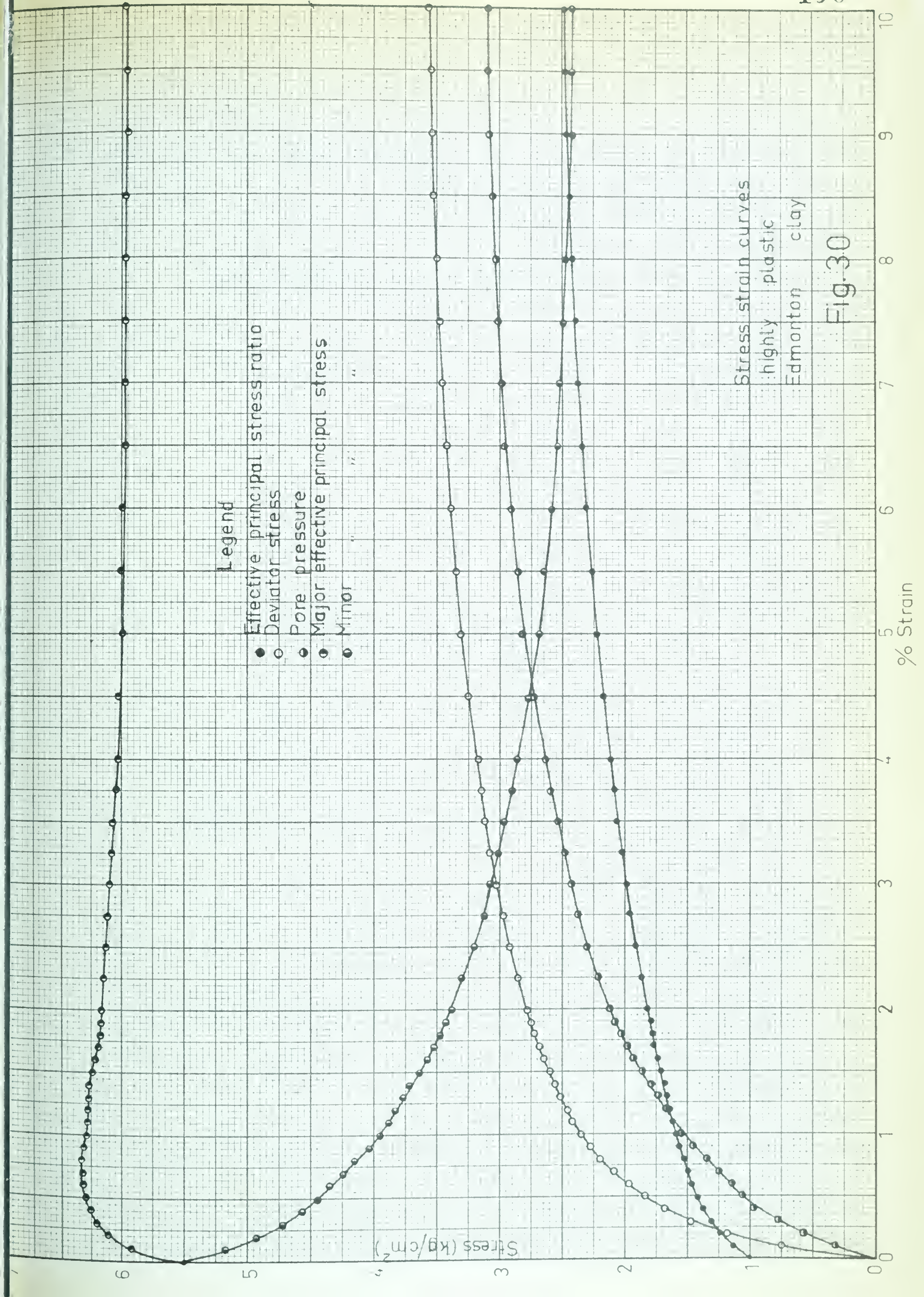
SOIL MECHANICS LABORATORY

TRIAXIAL COMPRESSION TEST

Project	Thesis
Sample No.	17
Test No.	4-75
Engineer	W.S.
Technician	W.S.
Date of test	23/2/62
Lateral pressure	5.5 kg/cm^2
Back pressure	2.0 kg/cm^2
Remarks	

SKETCH AT FAILURE

e	Strain Dial	A_c	Load Per Div.	Stress Dial	Deviator Stress	Pore Press.	Effective Stress		Stress Ratio	Axial Comp. Strain
n	Div.	cm^2	Kg.	Div.	Kg/cm^2	Kg/cm^2	Maj.	Min.		%
7	484	10.63	4277	702	3.39	2.91	5.98	2.59	2.309	6.0
1	525	10.68	4270	714	3.42	2.96	5.96	2.54	2.346	6.5
5	565	10.74	4268	725	3.45	2.98	5.97	2.52	2.369	7.0
0	605	10.80	4263	735	3.48	3.01	5.97	2.49	2.398	7.5
4	646	10.86	4259	745	3.50	3.03	5.97	2.47	2.417	8.0
7	686	10.92	4257	755	3.53	3.06	5.97	2.44	2.447	8.5
0	726	10.98	4253	763	3.54	3.09	5.95	2.41	2.469	9.0
5	767	11.04	4251	769	3.55	3.09	5.96	2.41	2.473	9.5
7	807	11.10	4249	777	3.57	3.09	5.98	2.41	2.481	10.0
1	847	11.16	4248	784	3.58	3.10	5.98	2.40	2.492	10.5
5	888	11.22	4243	792	3.59	3.11	5.98	2.39	2.502	11.0
8	928	11.29	4240	798	3.59	3.11	5.98	2.39	2.502	11.5
3	969	11.35	4239	804	3.60	3.12	5.98	2.38	2.513	12.0
5	1009	11.42	4238	810	3.60	3.12	5.98	2.38	2.513	12.5
8	1049	11.48	4237	812	3.59	3.13	5.96	2.37	2.515	13.0
3	1090	11.55	4235	815	3.58	3.13	5.95	2.37	2.511	13.5
5	1130	11.62	4234	816	3.56	3.13	5.93	2.37	2.502	14.0
9	1170	11.68	4233	817	3.55	3.13	5.92	2.37	2.498	14.5
2	1211	11.75	4236	815	3.52	3.13	5.89	2.37	2.485	15.0
4	1251	11.82	4237	812	3.49	3.13	5.86	2.37	2.473	15.5



Stress strain curves
highly plastic
Edmonton clay

Fig.30

UNIVERSITY OF ALBERTA
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SOIL MECHANICS LABORATORY
DATA FOR TRIAXIAL COMPRESSION
TEST

Project	Thesis
Sample No.	17
Test No.	4-75
Engineer	W.S.
Technician	W.S.

PORE PRESSURE REACTION TEST

(1 kg/cm^2 extra cell press)

Load		Unload	
Time Min.	Pore pressure kg/cm^2	Time Min.	Pore pressure kg/cm^2
0.0	0.00	0.0	0.79
0.1	.26	0.1	.54
0.25	.38	0.25	.48
0.5	.50	0.5	.34
1.0	.60	1.0	.29
2.0	.72	2.0	.22
3.0	.75	3.0	.16
4.0	.79	4.0	.14
5.0	.79	5.0	.12
		6.0	.02

FINAL MOISTURE CONTENT

Wet wt plus tare	121.7768
Dry wt plus tare	91.2921
Wt of water	30.4847
Wt and No. of tare	2.2202 (S-31 foil)
Wt of dry soil	89.0719
Final moisture content%	34.224 %

VOLUME BY MERCURY IMMERSION

Hg plus tare	578.05	741.40	633.79	685.62
tare	229.56	228.63	229.57	228.62
Wt of Hg	348.49	512.77	404.22	457.00

Average weight of Mercury = 861.24 gm.
Temperature of Mercury = 22.4 C

$$\text{Volume of specimen} = \frac{861.24}{13.5406} = 63.604 \text{ cm}^3$$

SAMPLE CALCULATIONS FOR TRIAXIAL TEST No. 4-75, CONFINING PRESSURE OF 5.5 kg/cm^2

Final moisture content	34.22 %
Wt. dry soil	89.0719 gm.

Initial Moisture content:

Wet wt. at start	136.2839 gm.
Wt dry soil	89.0719 gm.
Wt water at start test	47.2120 gm.

$$\text{Initial moisture content} = \frac{47.2120}{89.0719} \times 100$$

$$= 53.00\ \%$$

Final volume by mercury immersion	63.604 cm^3
Volume soil solids $= \frac{89.0719}{2.80} =$	31.812 cm^3
Volume voids at end test	31.792 cm^3

$$\text{Volume water at end test} = 89.0719 \times 0.3422$$
$$= 30.480\ \text{cm}^3$$

$$\text{and } e_f = \frac{31.792}{31.812} = 0.999$$

$$S_f = \frac{30.480}{31.792} = 95.87\ \%$$

Original volume by measurement	80.629 cm^3
Volume soil solids	31.892 cm^3
Volume voids at end test	48.817 cm^3

$$\text{Volume water at start of test} = 89.0719 \times 0.5300$$
$$= 47.208\ \text{cm}^3$$

$$\text{and } e_o = \frac{48.817}{31.812} = 1.535$$

$$S_o = \frac{47.208}{48.817} = 96.70\ \%$$

ANALYSIS OF EXPERIMENTAL ERROR FOR TRIAXIAL TEST

No. 4-75

Precision of Measurements

Pore pressure	± 0.01 kg/cm^2
Area correction factor	± 0.006
Strain gauge	± 1 unit = ± 0.01 mm.
Specimen diameter	± 0.01 mm.
Confining pressure	± 0.02 kg/cm^2

Proving ring ± 1 % of the measured force, (ref. 27)

Average original area of specimen (A_o)

$$A_o = \tfrac{1}{4}(A_t + 2A_c + A_b)$$

A_t:

$$\begin{aligned} d_t &= 35.95 \ \pm 0.02 \text{ mm.} \\ &= 35.95 \ \pm 0.0556 \ \% \\ A_t &= 1014.536 \ \pm 1.128 \text{ mm}^2 \end{aligned}$$

A_c:

$$\begin{aligned} d_c &= 35.73 \ \pm 0.02 \text{ mm.} \\ &= 35.73 \ \pm 0.0560 \ \% \\ A_c &= 1002.157 \ \pm 1.122 \text{ mm}^2 \end{aligned}$$

A_b:

$$\begin{aligned} d_b &= 35.29 \ \pm 0.02 \text{ mm.} \\ &= 35.29 \ \pm 0.0567 \ \% \\ A_b &= 977.626 \ \pm 1.109 \text{ mm}^2 \end{aligned}$$

$$\begin{aligned} A_o &= 999.119 \ \pm 4.481 \text{ mm}^2 \\ &= 999.119 \ \pm 0.448 \ \% \text{ mm}^2 \end{aligned}$$

Strain at failure

$$\begin{aligned} \mu &= \frac{1049 \pm 1}{80 \times 100} \\ &= 0.131 \ \pm 0.095 \ \% \end{aligned}$$

Corrected area (A_c)

$$\begin{aligned} A_c &= \frac{A_o}{1 - \mu} \\ &= \frac{999.119 \ \pm 0.448 \ \%}{0.869 \ \pm 0.014 \ \%} \\ &= 1149.734 \ \pm 0.462 \ \% \text{ mm}^2 \end{aligned}$$

Deviator stress ($\sigma_1 - \sigma_3$)

$$\sigma_1 - \sigma_3 = \frac{k \, \delta \, K}{A_c}$$

ANALYSIS OF EXPERIMENTAL ERROR FOR TRIAXIAL TEST

No. 4-75 (cont'd)

$$\sigma_1 - \sigma_3 = \frac{34.404 \pm 1.0\,\% \times 1.199 \pm 0.50\,\%}{11.497 \pm 0.462\,\%}$$
$$= 3.588 \pm 1.962\,\%$$
$$= 3.588 \pm 0.070$$

Major effective principal stress (σ_1')

$$\sigma_1' = (\sigma_1 - \sigma_3) + \sigma_3 - P_p$$
$$= (3.588 \pm 0.070) + (5.50 \pm 0.02) - (3.13 \pm 0.01)$$
$$= 5.958 \pm 1.678\,\%\ \mathrm{kg/cm^2}$$

Minor effective principal stress (σ_3')

$$\sigma_3' = (5.50 \pm 0.02) - (3.13 \pm 0.01)$$
$$= 2.37 \pm 0.03$$

Angle of shearing resistance (ϕ')

$$\phi' = \sin^{-1}\left[\frac{\sigma_1' - \sigma_3'}{\sigma_1' + \sigma_3'}\right]$$
$$= \sin^{-1} \frac{5.958 \pm 0.096 - 2.37 \pm 0.03}{5.958 \pm 0.096 + 2.37 \pm 0.03}$$
$$= \sin^{-1} 0.4308 \pm 5.025\,\%$$
$$= \sin^{-1} 0.4308 \pm 0.0216$$

and $\phi' = 25^\circ 32' \pm 1^\circ 22'$

TABLE 14

SUMMARY OF PORE PRESSURE REACTION TESTS FOR TRIAXIAL TESTS

C H Edmonton Clay		Edmonton Till	
Test No.	Pore pressure kg/cm^2	Test No.	Pore pressure kg/cm^2
1-35	0.92	1-35T	0.96
1-75	0.85	1-75T	0.97
2-35	0.84	2-35T	0.99
2-75	0.95	2-75T	0.84
3-35	0.95	3-35T	0.83
3-75	0.55	3-75T	0.84
4-35	0.88	4-35T	0.74
4-35 (rep.)	0.70	4-75T	1.00
4-75	0.72		
5-35	0.46	5-35T	0.92
5-75	0.72	5-75T	0.59

Note:

Pore pressures are those measured 2 minutes after application of additional cell pressure.

Tests at low temperature are identified by the number 35 in the test number. Those at high temperature have the number 75 in the test number.

APPENDIX II

TABLE 15

CALIBRATION OF THERMOCOUPLES USED IN CONSOLIDATION AND TRIAXIAL TESTS

Thermocouple No.	Use	Temperature from strip chart (^{o}F)
12	Consolidation test	32.8
13	Consolidation test	32.8
14	Consolidation test	32.8
15	Consolidation test	32.8
16	Consolidation test	32.8
2	Triaxial cell No. 1	32.9
9	Triaxial cell No. 1	32.8
6	Triaxial cell No. 2	32.8
14	Triaxial cell No. 3	32.8
16	Cold tank	32.9

Thermocouples were calibrated in a mixture of ice and water which was continuously stirred. Temperature of solution was noted to be 0.0^{o}C at all times.

TABLE 16

RECORD OF TEMPERATURE FOR TRIAXIAL TEST NO. 1-35

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
31/1/62		30	35.9	30	35.5
*12 00	35.6	8	35.8	4	35.8
30	35.8	30	35.7	30	35.8
13	35.6	9	35.7	5	35.8
30	35.7	30	35.4	30	35.8
14	35.5	10	35.7	6	35.6
30	35.7	30	35.7	30	35.8
15	35.8	11	35.5	7	35.8
30	35.8	30	35.9	30	35.8
16	35.7	12	35.0	8	36.0
30	35.9	30	35.4	30	35.0
17	35.8	13	35.5	9	35.5
30	35.9	30	35.9	30	36.0
18	35.9	14	35.9	10	36.2
30	35.8	30	35.7	30	36.0
19	35.9	15	35.9	11	36.2
30	35.7	30	35.8	30	36.1
20	35.7	16	35.8	12	36.1
30	35.6	30	35.7	30	35.5
21	35.7	17	35.9	13	33.8
30	35.9	30	35.9	30	35.2
22	35.9	18	35.6	14	36.0
30	36.0	30	35.7	30	36.0
23	36.0	19	35.6	15	36.2
30	36.0	30	35.7	30	35.8
24	36.0	20	35.7	16	36.1
30	35.7	30	35.7	30	36.2
1/2/62		21	35.7	17	36.2
1 00	35.8	30	35.7	30	36.1
30	35.9	22	35.7	18	36.0
2	35.8	30	35.7	30	36.0
30	35.8	23	35.8	19	36.0
3	35.0	30	35.9	** 30	36.2
30	35.6	24	35.5	20	36.1
4	36.0	30	35.6	30	36.5
30	35.5	2/2/62		21	36.5
5	35.6	1 00	35.5	30	36.5
30	35.7	30	35.9	22	36.5
6	35.7	2	35.6	30	36.6
30	35.7	30	35.6	23	36.6
7	35.5	3	35.7	30	36.2

TABLE 16 (Continued

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
24	36.5	5	34.5	30	36.2
30	36.4	30	34.8	11	36.2
3/2/62		6	35.6	30	36.0
1 00	36.4	30	35.7	12	35.7
30	36.2	7	36.0	30	36.0
2	36.2	30	36.1	13	35.6
30	36.3	8	36.0	30	35.7
3	36.0	30	36.0	14	35.8
30	36.2	9	36.1	30	35.6
4	36.2	30	36.1	15	36.0
30	36.2	10	35.6	30	36.2
				16	36.2

*Begin triaxial consolidation

**Set up cell on loading press and compress

Temperatures recorded with thermocouple No. 6

Temperatures not corrected for thermocouple calibration (-0.8°F)

TABLE 17

RECORD OF TEMPERATURE FOR TRIAXIAL TEST NO. 2-35

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
18/1/62		30	35.1	30	36.1
*9 30	35.7	4	35.4	23	36.2
10	35.7	30	35.7	30	36.4
30	35.7	5	35.6	24	36.0
11	35.5	30	35.4	30	36.1
30	35.5	6	35.5	20/1/62	
12	35.4	30	35.5	1 00	36.2
30	35.5	7	35.5	30	36.0
13	35.5	30	35.5	2	36.1
30	35.4	8	35.5	30	36.4
14	35.5	30	32.0	3	36.4
30	35.5	9	32.5	30	36.4
15	34.0	30	34.4	4	36.3
30	35.1	10	35.4	30	36.0
16	35.6	30	35.1	5	36.0
30	35.0	11	35.5	30	36.2
17	34.6	30	35.6	6	36.2
30	35.0	12	35.8	30	36.3
18	35.6	** 30	36.0	7	36.0
30	35.5	13	36.2	30	36.2
19	35.6	30	36.0	8	36.1
30	35.6	14	36.2	30	36.1
20	35.6	30	36.3	9	35.9
30	35.2	15	36.5	30	35.6
21	35.6	30	36.2	10	36.0
30	35.4	16	36.1	30	36.0
22	35.1	30	36.3	11	36.1
30	35.5	17	36.4	30	36.5
23	35.5	30	36.2	12	36.3
30	35.6	18	36.4	30	36.4
24	35.6	30	36.0	13	36.5
30	35.6	19	36.0	30	36.2
19/1/62		30	36.2	14	35.1
1 00	35.5	20	36.4	30	36.0
30	35.6	30	35.8	15	36.5
2	35.6	21	36.2	30	36.5
30	35.5	30	36.4	16	36.5
3	35.6	22	36.4	30	36.1

*Begin triaxial consolidation

**Set up cell on loading press and compress

Temperatures recorded with thermocouple No. 6
Temperatures not corrected for thermocouple calibration (-0.8 °F)

TABLE 18

RECORD OF TEMPERATURE FOR TRIAXIAL TEST NO. 3-35

Date and Time	Temp. °F
18/1/62	
*13 30	35.2
14	35.5
30	35.5
15	34.0
30	35.0
16	35.6
30	35.0
17	34.5
30	35.0
18	35.3
30	35.5
19	35.6
30	35.6
20	35.6
30	35.1
21	35.5
30	35.3
22	35.1
30	35.5
23	35.5
30	35.6
24	35.6
30	35.5
19/1/62	
1	35.5
30	
2	
30	
3	35.5
30	35.1
4	35.4
30	35.6
5	35.6
30	35.4
6	35.5
30	35.5
7	35.5
30	35.5
8	35.5
30	32.0
9	32.4
30	34.3
10	35.4
30	35.0
11	35.5
30	35.4
12	35.8
30	35.7
13	35.7
30	35.6
14	35.7
30	35.7
15	35.8
30	35.5
16	35.6
30	35.7
17	35.8
30	35.7
18	35.8
30	35.5
19	35.5
30	35.7
20	35.8
30	35.3
21	35.6
30	35.8
22	35.6
30	35.5
23	35.6
30	35.7
24	35.5
30	35.6
20/1/62	
1 00	35.6
30	35.6
2	35.6
30	35.7
3	35.7
30	35.7
4	35.8
30	35.5
5	35.6
30	35.6
6	35.7
30	35.8
7	35.5
30	35.6
8	35.7
30	35.6
9	35.4
30	35.2
10	35.5
30	35.6
11	35.6
30	35.7
12	35.7
30	35.8
13	35.9
30	35.6
14	34.3
30	35.5
15	35.8
30	35.8
16	35.8
30	35.6
17	35.8
30	35.9
18	36.0
30	35.5
19	35.7
30	35.8
20	35.9
30	36.0
21	35.7
** 30	36.0
22	36.2
30	36.1
23	35.1
30	35.9
24	36.1
30	36.1
21/1/62	
1 00	36.1
30	36.1
2	35.7

TABLE 18 (Continued)

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
30	35.0	30	36.3	30	36.0
3	36.0	9	36.0	15	36.4
30	36.2	30	35.8	30	36.5
4	36.2	10	36.0	16	36.3
30	36.2	30	36.1	30	36.7
5	36.2	11	36.2	17	36.7
30	35.5	30	36.2	30	36.5
6	35.8	12	36.3	18	36.8
30	36.0	30	36.3		
7	36.2	13	36.3		
30	35.9	30	36.2		
8	36.0	14	36.3		

*Begin triaxial consolidation

**Set up cell on loading press and compress

Temperatures recorded with thermocouple No. 14

Temperatures not corrected for thermocouple calibration (-0.8°F)

TABLE 19

RECORD OF TEMPERATURE FOR TRIAXIAL TEST NO. 4-35

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
24/1/62		30	35.5	8	35.8
15 30	35.8	12	35.7	30	35.8
16	35.8	30	35.7	9	35.2
30	35.8	13	35.8	30	35.8
17	36.0	30	35.8	10	35.6
30	36.0	14	35.8	30	36.0
18	36.0	30	35.6	11	36.0
30	36.0	15	35.1	30	35.8
19	35.8	30	35.6	12	35.0
30	35.8	16	35.8	30	35.2
20	36.0	30	35.8	13	35.8
30	35.7	17	35.6	30	36.0
21	35.7	30	35.9	14	36.0
30	35.5	18	35.8	30	36.1
22	35.6	30	35.9	15	36.0
30	35.8	19	35.7	30	36.0
23	35.8	30	35.8	16	36.0
30	35.5	20	35.5	30	36.0
24	35.7	30	35.5	17	35.5
30	35.8	21	35.7	30	35.8
25/1/62		30	35.7	18	36.0
1 00	35.5	22	35.8	30	35.8
30	35.5	30	35.7	19	35.7
2	35.7	23	35.7	30	35.8
30	35.7	30	35.7	**20	36.0
3	35.5	24	35.8	30	36.0
30	35.6	30	35.9	21	36.5
4	35.6	26/1/62		30	36.6
30	35.6	1 00	35.7	22	36.8
5	35.5	30	35.6	30	36.8
30	35.6	2	35.7	23	37.0
6	35.6	30	35.7	30	36.7
30	35.4	3	35.7	24	36.5
7	35.6	30	35.7	30	36.5
30	35.6	4	35.5	27/1/62	
8	35.6	30	35.8	1 00	36.5
30	35.6	5	35.7	30	36.5
9	35.7	30	35.7	2	36.5
30	35.5	6	35.9	30	36.3
10	35.6	30	36.0	3	36.6
30	35.6	7	35.7	30	36.5
11	35.0	30	35.8	4	36.5

TABLE 19 (Continued)

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
30	36.0	30	36.6	30	36.8
5	36.2	11	36.7	17	36.8
30	36.0	30	36.7	30	36.8
6	36.2	12	36.7	18	36.5
30	36.1	30	36.8	30	36.6
7	36.4	13	36.6	19	36.5
30	36.4	30	36.1	30	36.6
8	36.6	14	36.3	20	36.5
30	34.7	30	36.8	30	36.4
9	35.6	15	36.8	21	36.0
30	36.0	30	36.8		
10	36.3	16	36.8		

*Begin triaxial consolidation

**Set up cell on loading press and compress

Temperatures recorded with thermocouple No. 14

Temperatures not corrected for thermocouple calibration (-0.8°F)

TABLE 20

RECORD OF TEMPERATURE FOR TRIAXIAL TEST NO. 4-35 (rep.)

Date and Time	Temp. $^{\circ}$F	Date and Time	Temp. $^{\circ}$F	Date and Time	Temp. $^{\circ}$F
12/3/62		8	34.5	4	35.9
*12 30	35.7	30	35.5	30	35.5
13	35.8	9	36.0	5	35.7
30	35.5	30	35.8	30	35.2
14	35.8	10	35.9	6	35.6
30	35.8	30	36.0	30	35.5
15	35.7	11	35.9	7	34.8
30	35.9	30	36.0	30	33.2
16	35.9	12	35.9	8	34.7
30	35.4	30	35.6	30	35.5
17	34.7	13	35.7	9	35.6
30	35.9	30	36.0	30	35.8
18	35.7	14	35.7	10	35.4
30	35.7	30	35.9	30	35.6
19	35.7	15	35.5	11	35.1
30	35.8	30	36.0	30	30.9
20	36.0	16	36.0	12	31.5
30	35.6	30	35.6	30	33.6
21	35.6	17	33.1	13	35.0
30	35.9	30	34.0	30	35.2
22	35.9	18	35.4	14	35.0
30	35.9	30	35.4	30	34.4
23	35.9	19	35.9	15	32.6
30	35.9	30	36.3	30	34.6
24	35.7	20	35.9	16	35.2
30	35.6	30	35.7	30	35.4
13/3/62		21	35.5	17	35.4
1 00	35.8	30	34.8	30	33.8
30	35.3	22	35.6	18	35.0
2	35.7	30	35.1	30	34.8
30	35.5	23	35.2	19	34.0
3	35.8	30	35.8	30	35.0
30	34.5	24	35.8	20	35.2
4	32.3	30	34.6	30	35.3
30	33.8	14/3/62		21	35.3
5	35.3	1 00	35.5	30	35.4
30	33.0	30	35.7	22	35.0
6	33.8	2	35.9	30	35.3
30	35.5	30	35.8	23	35.2
7	35.7	3	35.3	30	35.2
30	35.4	30	35.5	24	35.4

TABLE 20 (Continued)

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
30	35.0	13	34.2	30	35.1
15/3/62		30	35.2	2	35.2
1 00	34.0	14	35.4	30	35.3
30	35.0	30	35.4	3	35.2
2	34.6	15	35.4	30	35.3
30	34.9	30	34.5	4	35.2
3	35.0	16	33.5	30	35.1
30	35.4	30	29.6	5	35.2
4	35.1	17	30.6	30	34.1
30	35.0	30	32.4	6	35.0
5	35.0	18	34.0	30	34.8
30	34.6	30	34.8	7	35.0
6	35.0	19	35.1	30	34.5
30	35.2	30	35.1	8	35.0
7	35.0	20	35.2	30	35.2
30	35.0	** 30	35.2	9	35.1
8	34.0	21	34.8	30	33.5
30	30.7	30	35.2	10	34.8
9	31.8	22	34.3	30	35.0
30	34.0	30	35.2	11	35.4
10	34.5	23	35.1	30	35.4
30	32.5	30	35.2	12	35.5
11	34.0	24	34.7	30	35.4
30	35.2	30	35.2	13	35.3
12	35.2	16/3/62		30	35.5
30	35.5	1 00	34.6	14	36.2

*Begin triaxial consolidation

**Set up cell on loading press and compress

Temperatures recorded with thermocouple No. 2

Temperatures not corrected for thermocouple calibration (-0.9°F)

TABLE 21

RECORD OF TEMPERATURE FOR TRIAXIAL TEST NO. 5-35

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
24/1/62		8	35.6	1 00	36.0
*15 30	35.8	30	35.6	30	35.8
16	35.8	9	35.7	2	36.0
30	35.8	30	35.5	30	36.0
17	36.0	10	35.6	3	36.0
30	36.0	30	35.6	30	36.0
18	36.0	11	35.0	4	35.7
30	36.0	30	35.5	30	36.0
19	35.8	12	35.7	5	36.0
30	35.8	30	35.7	30	36.0
20	36.0	13	35.8	6	36.0
30	35.7	30	35.8	30	36.0
21	35.7	14	35.8	7	36.0
30	35.5	30	35.6	30	36.0
22	35.6	15	35.1	8	36.0
30	35.8	30	35.6	30	36.0
23	35.8	16	35.8	9	35.5
30	35.5	30	35.8	30	36.0
24	35.7	17	35.6	10	35.8
30	35.8	30	35.9	30	36.0
25/1/62		18	35.8	11	36.1
1 00	35.5	30	35.9	30	35.9
30	35.5	19	35.7	12	34.9
2	35.7	30	35.8	30	35.2
30	35.7	**20	35.5	13	35.6
3	35.5	30	35.7	30	36.0
30	35.6	21	36.0	14	36.0
4	35.6	30	36.0	30	36.1
30	35.6	22	36.0	15	36.1
5	35.5	30	36.0	30	36.0
30	35.6	23	36.0	16	36.0
6	35.6	30	36.0	30	36.6
30	35.4	24	36.0	17	36.0
7	35.6	30	36.0	30	36.5
30	35.6	26/1/62		18	36.6

*Begin triaxial consolidation
**Set up cell on loading press and compress

Temperatures recorded with Thermocouple No. 6

Temperatures not corrected for thermocouple calibration (-0.8°F)

TABLE 22

RECORD OF TEMPERATURE FOR TRIAXIAL TEST NO. 1-75

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
14/2/62		9	78.7	5	79.4
13 30	79.0	30	78.7	30	79.4
14	79.0	10	78.7	6	79.2
30	79.1	30	78.7	30	79.1
15	79.1	11	78.7	7	79.1
30	79.2	30	78.7	30	79.1
16	79.3	12	78.8	8	79.0
30	79.3	30	78.8	30	78.8
17	79.4	13	78.9	9	78.8
30	79.5	30	79.0	30	78.8
18	79.5	14	79.0	10	78.8
30	79.6	30	79.1	30	79.0
19	79.7	15	79.2	11	79.0
30	79.6	30	79.3	30	79.0
20	79.7	16	79.3	12	79.1
30	79.7	30	79.4	30	79.4
21	79.7	17	79.5	13	79.6
30	79.9	30	79.6	30	80.0
22	79.9	18	79.7	14	80.0
30	79.9	30	79.8	30	80.4
23	79.9	19	79.8	15	80.4
30	79.8	30	79.8	30	80.7
24	79.8	20	79.7	16	80.9
30	79.9	30	79.7	30	81.4
15/2/62		21	79.7	17	81.5
1 00	79.8	30	79.9	30	81.6
30	79.7	22	80.0	18	81.6
2	79.7	30	80.0	30	81.7
30	79.6	23	80.1	19	81.7
3	79.5	30	80.1	** 30	81.7
30	79.5	24	80.1	20	81.6
4	79.5	30	80.2	30	81.4
30	79.4	16/2/62		21	81.3
5	79.3	1 00	80.0	30	81.2
30	79.2	30	80.0	22	81.0
6	79.1	2	80.0	30	81.0
30	79.0	30	80.0	23	80.9
7	79.0	3	79.8	30	80.7
30	79.0	30	79.7	24	80.6
8	78.9	4	79.6	30	80.5
30	78.7	30	79.5	17/2/62	-

TABLE 22 (Continued)

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
1 00	80.5	6	79.4	11	78.7
30	80.0	30	79.3	30	78.8
2	80.0	7	79.3	12	78.9
30	79.9	30	79.0	30	79.0
3	80.0	8	79.0	13	79.0
30	80.0	30	78.9	30	79.0
4	79.7	9	78.8	14	79.1
30	79.6	30	78.8	30	79.6
5	79.5	10	78.7	15	79.3
30	79.5	30	78.7	30	79.4
				16	79.5

*Begin triaxial consolidation

**Set up cell on loading press and compress

Temperatures recorded with thermocouple No. 2

Temperatures not corrected for thermocouple calibration (-0.9°F)

TABLE 23

RECORD OF TEMPERATURE FOR TRIAXIAL TEST NO. 2-75

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
16/2/62		30	79.1	30	78.7
*21 00	80.4	12	79.3	3	78.6
30	80.5	30	79.5	30	78.5
22	80.5	13	79.7	4	78.5
30	80.5	30	80.0	30	78.3
23	80.5	14	80.0	5	78.2
30	80.5	30	80.5	30	78.0
24	80.5	15	80.6	6	78.0
30	80.5	30	81.0	30	78.0
17/2/62		16	81.2	7	77.9
1 00	80.5	30	81.2	30	77.7
30	80.2	17	81.0	8	77.6
2	80.1	30	80.9	30	77.5
30	80.0	18	80.7	9	77.4
3	80.0	30	80.5	30	77.4
30	80.0	19	80.5	10	77.3
4	80.0	30	80.1	30	77.3
30	79.7	**20	80.0	11	77.3
5	79.7	30	80.0	30	77.4
30	79.5	21	80.0	12	77.4
6	79.5	30	79.9	30	77.5
30	79.4	22	79.9	13	77.6
7	79.3	30	79.8	30	77.7
30	79.1	23	79.6	14	77.8
8	79.0	30	79.5	30	77.9
30	79.0	24	79.3	15	78.0
9	78.9	30	79.2	30	78.0
30	78.9	18/2/62		16	78.0
10	78.9	1 00	79.1		
30	79.0	30	79.0		
11	79.0	2	79.0		

*Begin triaxial consolidation

**Set up cell on loading press and compress

Temperatures recorded with thermocouple No. 6

Temperatures not corrected for thermocouple calibration (-0.8°F)

TABLE 24

RECORD OF TEMPERATURE FOR TRIAXIAL TEST NO. 3-75

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
20/2/62		8	76.7	30	78.4
*15 00	77.4	30	76.6	2	78.4
30	77.0	9	76.5	30	78.1
16	77.0	30	76.5	3	78.0
30	77.0	10	76.5	30	78.0
17	77.2	30	76.5	4	78.0
30	77.1	11	76.6	30	78.0
18	77.2	30	76.7	5	77.7
30	77.2	12	76.8	30	77.6
19	77.2	30	76.9	6	77.5
30	77.3	13	77.0	30	77.4
20	77.3	30	77.0	7	77.3
30	77.3	14	77.0	30	77.2
21	77.4	30	77.1	8	77.2
30	77.4	15	77.2	30	77.2
22	77.5	30	77.3	9	77.2
30	77.5	16	77.3	30	77.1
23	77.5	30	77.4	10	77.1
30	77.5	17	77.4	30	77.2
24	77.5	30	77.5	11	77.5
30	77.5	18	77.5	30	77.5
21/2/62		30	77.6	12	77.6
1 00	77.5	19	77.6	30	77.9
30	77.4	** 30	77.6	13	78.0
2	77.3	20	77.8	30	78.3
30	77.3	30	77.8	14	78.6
3	77.3	21	77.9	30	79.0
30	77.2	30	78.0	15	79.1
4	77.2	22	78.1	30	79.5
30	77.4	30	78.2	16	79.6
5	77.3	23	78.4	30	79.9
30	77.0	30	78.4	17	80.0
6	77.0	24	78.4	30	80.2
30	76.8	30	78.3		
7	76.8	22/2/62			
30	76.7	1 00	78.3		

*Begin triaxial consolidation
**Set up cell on loading press and compress

Temperatures recorded with thermocouple No. 2
Temperatures not corrected for thermocouple calibration (-0.9°F)

TABLE 25

RECORD OF TEMPERATURE FOR TRIAXIAL TEST NO. 4-75

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
20/2/62		30	76.8	30	77.5
*15 00	77.4	11	76.8	7	77.4
30	77.3	30	76.9	30	77.4
16	77.3	12	77.0	8	77.3
30	77.4	30	77.1	30	77.2
17	77.4	13	77.1	9	77.2
30	77.5	30	77.2	30	77.1
18	77.5	14	77.3	10	77.2
30	77.5	30	77.4	30	77.2
19	77.5	15	77.5	11	77.4
30	77.5	30	77.5	30	77.5
20	77.6	16	77.6	12	77.6
30	77.7	30	77.8	30	77.6
21	77.7	17	77.8	13	77.8
30	77.7	30	77.8	30	77.9
22	77.8	18	77.9	14	78.0
30	77.8	30	77.9	30	78.2
23	77.8	19	78.0	15	78.3
30	77.8	30	78.0	30	78.4
24	77.8	20	78.0	16	78.5
30	77.8	30	78.0	30	78.7
21/2/62		21	78.0	17	78.9
1 00	77.8	30	78.3	30	79.0
30	77.7	22	78.3	**18	79.0
2	77.6	30	78.3	30	79.0
30	77.6	23	78.4	19	79.1
3	77.6	30	78.4	30	79.1
30	77.4	24	78.4	20	79.1
4	77.4	30	78.3	30	79.3
30	77.4	22/2/62		21	79.5
5	77.3	1 00	78.3	30	79.6
30	77.1	30	78.3	22	79.7
6	77.1	2	78.2	30	79.7
30	77.0	30	78.1	23	79.8
7	77.0	3	78.0	30	79.8
30	77.0	30	78.0	24	79.8
8	77.0	4	78.0	30	79.8
30	77.8	30	78.0	23/2/62	
9	76.7	5	77.8	1 00	79.6
30	76.7	30	77.7	30	79.5
10	76.7	6	77.6	2	79.5

TABLE 25 (Continued)

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
30	79.4	30	77.9	30	78.1
3	79.0	8	77.8	13	78.4
30	79.0	30	77.6	30	78.7
4	78.9	9	77.5	14	79.0
30	78.7	30	77.5	30	78.8
5	78.6	10	77.5	15	79.4
30	78.5	30	77.6	30	79.5
6	78.4	11	77.7	16	79.8
30	78.2	30	77.9	30	80.0
7	78.0	12	78.0	17	80.0

*Begin triaxial consolidation

**Set up cell on loading press and compress

Temperatures recorded with thermocouple No. 6

Temperatures not corrected for thermocouple calibration (-0.8°F)

TABLE 26

RECORD OF TEMPERATURE FOR TRIAXIAL TEST NO. 5-75

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
21/2/62		9	77.3	5	78.6
*13 30	77.5	30	77.3	30	78.5
14	77.5	10	77.3	6	78.4
30	77.6	30	77.4	30	78.2
15	77.7	11	77.5	7	78.0
30	77.8	30	77.7	30	77.9
16	77.8	12	77.9	8	77.8
30	78.0	30	77.9	30	77.7
17	77.9	13	78.0	9	77.5
30	78.0	30	78.3	30	77.5
18	78.0	14	78.4	10	77.5
30	78.0	30	78.5	30	77.6
19	78.1	15	78.7	11	77.7
30	78.1	30	78.9	30	77.9
20	78.1	16	79.1	12	78.0
30	78.2	30	79.2	30	78.1
21	78.3	17	79.3	13	78.2
30	78.4	30	79.5	30	78.4
22	78.5	18	79.6	14	78.5
30	78.5	30	79.7	30	78.4
23	78.6	19	79.7	15	78.7
30	78.6	30	79.7	30	78.9
24	78.5	20	79.7	16	79.0
30	78.5	30	79.7	30	79.1
22/2/62		21	79.8	17	79.2
1 00	78.5	30	79.9	30	79.4
30	78.5	22	79.9	18	79.4
2	78.3	30	79.9	30	79.3
30	78.3	23	79.9	**19	79.3
3	78.3	30	79.9	30	79.3
30	78.1	24	79.8	20	79.4
4	78.0	30	79.8	30	79.5
30	78.0	23/2/62		21	79.5
5	78.0	1 00	79.6	30	79.6
30	77.9	30	79.5	22	79.6
6	77.8	2	79.5	30	79.6
30	77.6	30	79.4	23	79.5
7	77.6	3	79.0	30	79.4
30	77.5	30	79.0	24	79.4
8	77.4	4	78.9	30	79.0
30	77.3	30	78.7	24/2/62	

TABLE 26 (Continued)

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
1 00	79.0	30	76.9	14	77.6
30	78.8	8	76.9	30	77.9
2	78.6	30	76.8	15	78.0
30	78.5	9	76.6	30	78.4
3	78.3	30	76.6	16	78.5
30	78.1	10	76.7	30	78.8
4	78.0	30	76.6	17	79.0
30	77.8	11	76.6	30	79.2
5	77.7	30	76.7	18	79.4
30	77.5	12	76.9	30	79.6
6	77.4	30	77.0	19	79.8
30	77.2	13	77.0	30	79.9
7	77.0	30	77.3		

*Begin triaxial consolidation

**Set up cell on loading press and compress

Temperatures recorded with thermocouple No. 14.

Temperatures not corrected for thermocouple calibration (-0.8°F)

TABLE 27

RECORD OF TEMPERATURE FOR TRIAXIAL TEST NO. 1-35T

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
4/3/62		11	35.0	3	36.0
*19 30	34.6	30	34.8	30	36.1
20	35.0	12	35.0	4	35.9
30	35.0	30	34.8	30	36.0
21	35.0	13	35.0	5	35.9
30	35.2	30	35.3	30	35.9
22	35.2	14	35.0	6	35.9
30	35.0	30	35.0	30	35.6
23	35.2	15	35.1	7	34.9
30	35.5	30	33.9	30	35.4
24	35.2	16	32.6	8	35.8
30	35.2	30	34.5	30	35.8
5/3/62		17	35.2	9	35.7
1 00	35.0	30	33.4	30	35.9
30	35.2	18	32.5	10	36.1
2	35.0	30	34.5	30	35.8
30	34.0	**19	35.2	11	36.0
3	35.0	30	35.2	30	
30	35.0	20	35.0	12	35.8
4	35.0	30	35.0	30	36.2
30	35.0	21	34.0	13	36.1
5	34.8	30	35.2	30	34.3
30	33.8	22	35.6	14	35.6
6	35.0	30	35.9	30	36.0
30	33.0	23	36.0	15	36.2
7	34.0	30	36.1	30	36.2
30	35.0	24	36.0	16	36.3
8	35.0	30	36.0	30	36.2
30	35.2	6/3/62		17	36.3
9	35.0	1 00	36.0	30	36.3
30	35.3	30	35.5	18	36.3
10	35.2	2	35.5	30	36.2
30	35.0	30	35.6	19	36.0

*Begin triaxial consolidation

**Set up cell on loading press and compress

Temperatures recorded with thermocouple No. 2

Temperatures not corrected for thermocouple calibration (-0.9°F)

TABLE 28

RECORD OF TEMPERATURE FOR TRIAXIAL TEST NO. 2-35T

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
4/3/62		30	35.0	10	35.9
*19 30	34.6	15	35.2	30	35.4
20	35.2	30	33.7	11	35.6
30	35.2	16	32.6	30	-
21	35.0	30	34.5	12	35.8
30	35.2	17	35.2	30	36.0
22	35.2	30	33.0	13	35.8
30	35.0	18	32.5	30	34.0
23	35.2	30	34.5	14	35.5
30	35.5	19	35.2	30	35.7
24	35.3	30	35.2	15	35.8
30	35.3	20	35.0	30	35.8
5/3/62		30	35.0	16	36.0
1 00	35.0	21	33.9	30	36.0
30	35.2	30	35.2	17	36.0
2	35.0	22	35.5	30	36.0
30	34.0	30	35.6	18	36.0
3	35.0	23	35.8	30	36.0
30	35.0	30	35.7	19	35.6
4	35.2	24	35.7	30	36.0
30	35.2	30	35.6	**20	35.7
5	34.8	6/3/62		30	36.0
30	33.8	1 00	35.8	21	36.0
6	35.0	30	35.1	30	36.0
30	32.8	2	35.4	22	36.2
7	34.0	30	35.4	30	36.0
30	35.0	3	35.6	23	36.1
8	35.0	30	35.9	30	36.0
30	35.2	4	35.6	24	36.1
9	35.0	30	35.7	30	36.2
30	35.3	5	35.6	7/3/62	
10	35.3	30	35.6	1 00	35.8
30	35.0	6	35.6	30	36.0
11	35.0	30	35.5	2	36.0
30	35.0	7	34.6	30	35.9
12	35.1	30	35.3	3	35.8
30	34.8	8	35.4	30	36.0
13	35.2	30	35.5	4	36.0
30	35.4	9	35.6	30	35.8
14	35.0	30	35.6	5	35.9

TABLE 28 (Continued)

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
30	36.0	30		30	36.3
6	35.4	11	36.5	16	36.2
30	35.8	30	35.5	30	36.6
7	35.5	12	36.4	17	36.5
30	36.0	30	36.5	30	35.9
8	35.9	13	35.7	18	36.3
30	36.0	30	36.2	30	36.2
9	36.0	14	36.2	19	36.4
30		30	36.5	30	36.4
10		15	36.6		

*Begin triaxial consolidation

**Set up cell on loading press and compress

Temperatures recorded with thermocouple No. 6

Temperatures not corrected for thermocouple calibration (-0.8°F)

TABLE 29

RECORD OF TEMPERATURE FOR TRIAXIAL TEST NO. 3-35T

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
5/3/62		8	35.8	30	36.0
*13 00	35.6	30	36.0	4	36.0
30	35.8	9	36.0	30	36.0
14	35.4	30	36.0	5	36.0
30	35.5	10	36.2	30	36.0
15	35.6	30	35.6	6	35.5
30	34.6	11	36.0	30	35.9
16	33.0	30	-	7	35.8
30	35.0	12	35.9	30	36.3
17	35.6	30	36.2	8	36.0
30	33.7	13	36.1	30	36.1
18	33.0	30	34.3	9	36.2
30	35.0	14	35.7	30	-
19	35.5	30	36.0	10	-
30	35.6	15	36.2	30	-
20	35.5	30	36.2	11	36.6
30	35.5	16	36.3	30.	35.6
21	34.0	30	36.3	12	36.3
30	35.6	17	36.3	30	36.4
22	36.0	30	36.3	13	35.8
30	36.0	18	36.3	30	36.2
23	36.0	30	36.3	14	36.0
30	36.1	19	36.0	30	36.3
24	36.0	30	36.3	15	36.4
30	36.0	20	36.2	30	36.4
6/3/62		30	36.4	16	36.2
1 00	36.0	21	36.2	30	36.5
30	35.6	30	36.1	17	36.3
2	35.5	22	36.2	30	36.0
30	35.7	30	36.0	18	36.1
3	36.0	23	36.1	30	36.4
30	36.1	30	36.1	19	36.5
4	36.0	24	36.2	30	36.5
30	36.0	30	36.2	**20	36.5
5	36.0	7/3/62		30	36.6
30	36.0	1 00	36.0	21	36.1
6	36.0	30	36.1	30	36.6
30	35.9	2	36.0	22	37.0
7	35.0	30	36.0	30	37.2
30	35.6	3	36.0	23	37.0

TABLE 29 (Continued)

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
30	36.6	6	36.7	13	36.8
24	36.6	30	36.7	30	36.0
30	37.0	7	36.7	14	37.2
8/3/62		30	34.5	30	37.1
1 00	37.0	8	34.6	15	37.1
30	36.7	30	36.2	30	37.2
2	36.8	9	36.5	16	37.0
30	36.9	30	34.9	30	37.0
3	36.7	10	34.2	17	37.0
30	36.6	30	36.0	30	37.0
4	36.8	11	36.5	18	37.0
30	36.6	30	35.9	30	36.8
5	35.8	12	37.0	19	36.6
30	36.6	30	36.8	30	36.4

*Begin triaxial consolidation

**Set up cell on loading press and compress

Temperatures recorded with thermocouple No. 14

Temperatures not corrected for thermocouple calibration (-0.8°F)

TABLE 30

RECORD OF TEMPERATURE FOR TRIAXIAL TEST NO. 4-35T

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
12/3/62		3	36.0	22	36.4
*9 00	35.0	30	34.8	30	35.8
30	35.2	4	32.5	23	36.0
10	35.6	30	34.0	30	36.5
30	35.7	5	35.4	24	36.5
11	36.1	30	33.0	30	35.2
30	36.3	6	33.9	14/3/62	
12	36.3	30	35.5	1 00	36.0
30	36.0	7	36.0	30	36.4
13	36.2	30	35.8	2	36.6
30	36.1	8	34.7	30	36.7
14	36.2	30	35.8	3	36.1
30	36.2	9	36.2	30	36.0
15	36.1	30	36.2	4	36.5
30	36.2	10	36.2	30	36.4
16	36.2	30	36.2	5	36.5
30	35.8	11	36.2	30	36.0
17	35.1	30	36.3	6	36.4
30	36.0	12	36.1	30	36.2
18	36.1	30	35.8	7	35.5
30	36.1	13	36.0	30	33.7
19	36.0	30	36.2	8	35.1
30	36.1	14	36.2	30	36.0
20	36.3	30	36.3	9	36.3
30	36.1	15	35.8	30	36.9
21	36.1	30	36.2	10	36.2
30	36.3	16	36.3	30	36.5
22	36.2	30	36.0	11	35.8
30	36.2	17	33.3	30	31.6
23	36.3	30	34.0	12	31.9
30	36.3	18	35.6	30	34.0
24	36.2	30	36.3	13	35.4
30	35.8	19	36.3	30	35.6
13/3/62		** 30	36.2	14	35.4
1 00	36.2	20	36.4	30	34.6
30	35.7	30	36.7	15	33.0
2	36.1	21	36.2	30	35.0
30	35.8	30	35.6	16	35.6

*Begin triaxial consolidation
**Set up cell on loading press and compress

Temperatures recorded with thermocouple No. 6
Temperatures not corrected for thermocouple calibration (-0.8°F)

TABLE 31

RECORD OF TEMPERATURE FOR TRIAXIAL TEST NO. 5-35T

Date and Time	Temp. °F
12/3/62	
*9 30	35.6
10	35.8
30	35.9
11	36.2
30	36.4
12	36.4
30	36.1
13	36.4
30	36.2
14	36.3
30	36.3
15	36.4
30	36.4
16	36.4
30	36.0
17	35.4
30	36.1
18	36.3
30	36.2
19	36.3
30	36.3
20	36.5
30	36.3
21	36.3
30	36.5
22	36.5
30	36.5
23	36.5
30	36.5
24	36.4
30	36.0
13/3/62	
1 00	36.3
30	36.0
2	36.3
30	36.0
3	36.2
30	35.0
4	32.8
30	34.2
5	35.8
30	33.6
6	34.0
30	35.7
7	36.3
30	36.0
8	34.9
30	36.0
9	36.5
30	36.5
10	36.4
30	36.5
11	36.5
30	36.5
12	36.4
30	36.0
13	36.2
30	36.5
14	36.4
30	36.5
15	36.2
30	36.5
16	36.5
30	36.2
17	33.7
30	34.3
18	35.8
30	36.5
19	36.5
30	36.4
20	36.4
30	36.3
21	36.0
30	35.2
22	36.0
30	35.6
23	35.7
30	36.2
24	36.2
30	35.0
14/3/62	
1 00	35.9
30	36.0
2	36.2
30	36.2
3	35.7
30	35.8
4	36.2
30	36.0
5	36.2
30	35.7
6	36.0
30	36.0
7	35.4
30	33.6
8	35.2
30	35.9
9	36.0
30	36.3
10	35.9
30	36.0
11	35.7
30	31.2
12	31.8
30	34.0
13	35.2
30	35.6
14	35.4
30	34.9
15	33.0
30	34.9
16	35.5
30	35.7
17	35.8
30	34.3
18	35.2
30	35.3
**19	34.5
30	35.7
20	36.0
30	36.3
21	36.3

TABLE 31 (Continued)

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
30	36.1	30	36.0	12	36.0
22	35.9	5	35.8	30	36.4
30	36.2	30	35.5	13	35.2
23	36.0	6	35.8	30	36.0
30	36.0	30	35.9	14	36.3
24	36.0	7	35.9	30	36.4
30	35.8	30	35.9	15	36.5
15/3/62		8	34.8	30	35.6
1 00	34.9	30	31.5	16	34.5
30	35.6	9	32.3	30	31.6
2	35.5	30	34.6	17	31.4
30	35.5	10	35.3	30	33.2
3	35.7	30	33.3	18	35.0
30	36.1	11	34.5	30	35.7
4	36.0	30	36.0	19	36.0
				30	36.0

*Begin triaxial consolidation

**Set up cell on loading press and compress

Temperatures recorded with thermocouple No. 14

Temperatures not corrected for thermocouple calibration (-0.8°F)

TABLE 32

RECORD OF TEMPERATURE FOR TRIAXIAL TEST NO. 1-75T

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
21/3/62		6	76.8	24	78.4
*13 00	76.5	30	76.7	30	78.5
30	76.6	7	76.7	23/3/62	
14	76.6	30	76.7	1 00	78.5
30	76.8	8	76.6	30	78.5
15	77.0	30	76.5	2	78.5
30	77.0	9	76.5	30	78.5
16	77.1	30	76.6	3	78.5
30	77.1	10	76.6	30	78.5
17	77.2	30	76.6	4	78.5
30	77.3	11	76.6	30	78.4
18	77.3	30	76.7	5	78.4
30	77.3	12	76.7	30	78.4
19	77.3	30	76.8	6	78.3
30	77.3	13	77.0	30	78.3
20	77.3	30	77.0	7	78.2
30	77.3	14	77.0	30	78.1
21	77.3	30	77.0	8	78.0
30	77.3	15		30	78.0
22	77.3	30	77.5	9	78.0
30	77.3	16	77.6	30	78.0
23	77.3	30	77.6	10	78.1
30	77.3	17	77.6	30	78.3
24	77.2	30	77.6	11	78.4
30	77.2	18	77.6	30	78.5
22/3/62		30	77.6	12	78.7
1 00	77.1	19	77.6	30	78.9
30	77.1	30	77.6	13	79.1
2	77.1	20	77.7	30	79.4
30	77.1	** 30	77.8	14	79.5
3	77.1	21	77.8	30	79.9
30	77.0	30	78.0	15	79.9
4	77.0	22	78.0	30	80.0
30	77.0	30	78.1	16	80.2
5	77.0	23	78.2		
30	76.8	30	78.3		

*Begin triaxial consolidation
**Set up cell on loading press and compress

Temperatures recorded with thermocouple No. 2
Temperatures not corrected for thermocouple calibration (-0.9°F)

TABLE 33

RECORD OF TEMPERATURE FOR TRIAXIAL TEST NO. 2-75T

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
21/3/62		9	76.8	5	78.4
*13 30	77.0	30	76.8	30	78.4
14	77.0	10	76.8	6	78.4
30	77.2	30	76.8	30	78.4
15	77.3	11	76.9	7	78.3
30	77.4	30	77.0	30	78.1
16	77.5	12	77.1	8	78.1
30	77.5	30	77.2	30	78.1
17	77.6	13	77.2	9	78.0
30	77.6	30	77.3	30	78.0
18	77.7	14	77.4	10	78.1
30	77.8	30	77.4	30	78.3
19	77.8	15		11	78.4
30	77.8	30	77.7	30	78.5
20	77.8	16	77.8	12	78.6
30	77.8	30	77.8	30	78.8
21	77.8	17	77.9	13	78.9
30	77.8	30	77.9	30	79.0
22	77.6	18	77.9	14	79.1
30	77.6	30	77.9	30	79.4
23	77.6	19	78.0	15	79.4
30	77.6	30	78.0	30	79.7
24	77.6	20	78.0	16	79.9
30	77.6	30	78.1	30	80.0
22/3/62		21	78.2	17	80.1
1 00	77.5	30	78.3	30	80.2
30	77.5	22	78.4	18	80.3
2	77.5	30	78.5	30	80.4
30	77.5	23	78.5	19	80.5
3	77.5	30	78.6	** 30	80.5
30	77.4	24	78.6	20	80.6
4	77.4	30	78.7	30	80.8
30	77.4	23/3/62		21	81.0
5	77.4	1 00	78.7	30	81.0
30	77.1	30	78.6	22	81.1
6	77.1	2	78.6	30	81.3
30	77.0	30	78.6	23	81.3
7	77.0	3	78.6	30	81.3
30	77.0	30	78.6	24	81.4
8	76.9	4	78.6	30	81.4
30	76.8	30	78.5	24/3/62	

TABLE 33 (Continued)

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
1 00	81.4	30	80.3	12	80.3
30	81.5	7	80.2	30	80.5
2	81.4	30	80.0	13	80.7
30	81.2	8	80.0	30	81.0
3	81.1	30	79.9	14	81.0
30	81.0	9	79.9	30	81.3
4	80.9	30	79.8	15	81.4
30	80.7	10	79.9	30	81.6
5	80.6	30	80.0	16	81.8
30	80.4	11	80.0	30	82.0
6	80.4	30	80.1	17	82.0

*Begin triaxial consolidation

**Set up cell on loading press and compress

Temperatures recorded with thermocouple No. 6

Temperatures not corrected for thermocouple calibration (-0.8°F)

TABLE 34

RECORD OF TEMPERATURE FOR TRIAXIAL TEST NO. 3-75T

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
21/3/62		9	76.9	30	78.6
*14 00	77.2	30	77.0	5	78.5
30	77.4	10	77.0	30	78.5
15	77.5	30	77.0	6	78.5
30	77.6	11	77.0	30	78.4
16	77.6	30	77.0	7	78.4
30	77.6	12	77.1	30	78.3
17	77.7	30	77.3	8	78.3
30	77.9	13	77.3	30	78.2
18	77.9	30	77.4	9	78.1
30	78.0	14	77.5	30	78.1
19	78.0	30	77.5	10	78.3
30	78.0	15		30	78.4
20	78.0	30	77.9	11	78.5
30	78.0	16	78.0	30	78.7
21	78.0	30	77.0	12	78.9
30	78.0	17	77.0	30	79.0
22	77.9	30	77.0	13	79.1
30	77.9	18	77.0	30	79.4
23	77.9	30	77.0	14	79.5
30	77.9	19	78.1	30	79.7
24	77.7	30	78.1	15	79.8
30	77.7	20	78.2	30	80.0
22/3/62		30	78.3	16	80.1
1 00	77.6	21	78.3	30	80.5
30	77.6	30	78.4	17	80.6
2	77.6	22	78.5	30	80.7
30	77.5	30	78.5	18	80.8
3	77.5	23	78.6	30	80.9
30	77.4	30	78.7	19	80.9
4	77.4	24	78.7	30	80.9
30	77.4	30	78.7	20	80.9
5	77.4	23/3/62		30	81.0
30	77.3	1 00	78.8	21	81.0
6	77.3	30	78.7	30	81.0
30	77.1	2	78.7	22	81.1
7	77.1	30	78.7	30	81.1
30	77.1	3	78.7	23	81.1
8	77.0	30	78.7	30	81.1
30	76.9	4	78.7	24	81.2

TABLE 34 (Continued)

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
30	81.2	15	81.0	30	80.1
24/3/62		30	81.2	6	80.0
1 00	81.2	16	81.3	30	80.0
30	81.1	30	81.5	7	79.9
2	81.1	17	81.5	30	79.8
30	81.0	30	81.5	8	79.7
3	80.9	18	81.6	30	79.5
30	80.7	30	81.8	9	79.5
4	80.6	**19	81.9	30	79.5
30	80.5	30	81.9	10	79.5
5	80.4	20	82.0	30	79.5
30	80.2	30	82.0	11	79.6
6	80.2	21	82.0	30	79.7
30	80.1	30	82.0	12	79.8
7	80.0	22	82.0	30	79.9
30	80.0	30	81.9	13	80.0
8	80.0	23	81.8	30	80.1
30	79.9	30	81.6	14	80.2
9	79.9	24	81.5	30	80.3
30	79.7	30	81.4	15	80.5
10	79.8	25/3/62		30	80.6
30	79.9	1 00	81.3	16	80.8
11	80.0	30	81.0	30	80.9
30	80.0	2	81.0	17	81.0
12	80.2	30	80.8	30	81.1
30	80.4	3	80.7	18	81.1
13	80.5	30	80.5	30	81.2
30	80.6	4	80.5	19	81.3
14	80.7	30	80.3	30	81.3
30	80.9	5	80.2		

*Begin triaxial consolidation

**Set up cell on loading press and compress

Temperatures recorded with thermocouple No. 14

Temperatures not corrected for thermocouple calibration (-0.8°F)

TABLE 35

RECORD OF TEMPERATURE FOR TRIAXIAL TEST NO. 4-75T

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
27/3/62		30	77.6	11	77.7
*19 00	78.5	3	77.6	30	77.8
30	78.5	30	77.6	12	77.8
20	78.5	4	77.6	30	78.0
30	78.5	30	77.6	13	78.0
21	78.5	5	77.6	30	78.0
30	78.5	30	77.6	14	78.1
22	78.4	6	77.6	30	78.2
30	78.3	30	77.6	15	78.3
23	78.1	7	77.6	30	78.3
30	78.0	30	77.6	16	78.4
24	78.0	8	77.6	30	78.4
30	77.9	30	77.6	17	78.5
28/3/62		9	77.6	30	78.5
1 00	77.9	30	77.6	18	78.5
30	77.8	10	77.6	30	78.6
2	77.7	30	77.7	19	78.6

*Begin triaxial consolidation

Temperatures are for the period of consolidation only account recorder failed

Temperatures recorded with thermocouple No. 6

Temperatures not corrected for thermocouple calibration (-0.8°F)

TABLE 36

RECORD OF TEMPERATURE FOR TRIAXIAL TEST NO. 5-75T

Date and Time	Temp. °F	Date and Time	Temp. °F	Date and Time	Temp. °F
27/3/62		3	77.8	30	78.0
*19 00	78.6	30	77.8	12	78.0
20	78.6	4	77.8	30	78.2
30	78.6	30	77.8	13	78.2
21	78.6	5	77.8	30	78.3
30	78.6	30	77.8	14	78.3
22	78.5	6	77.8	30	78.4
30	78.4	30	77.8	15	78.5
23	78.3	7	77.8	30	78.5
30	78.3	30	77.8	16	78.6
24	78.2	8	77.7	30	78.6
30	78.1	30	77.7	17	78.7
28/3/62		9	77.7	30	78.7
1 00	78.1	30	77.7	18	78.7
30	77.9	10	77.8	30	78.7
2	77.9	30	77.9	19	78.8
30	77.8	11	78.0	30	78.8

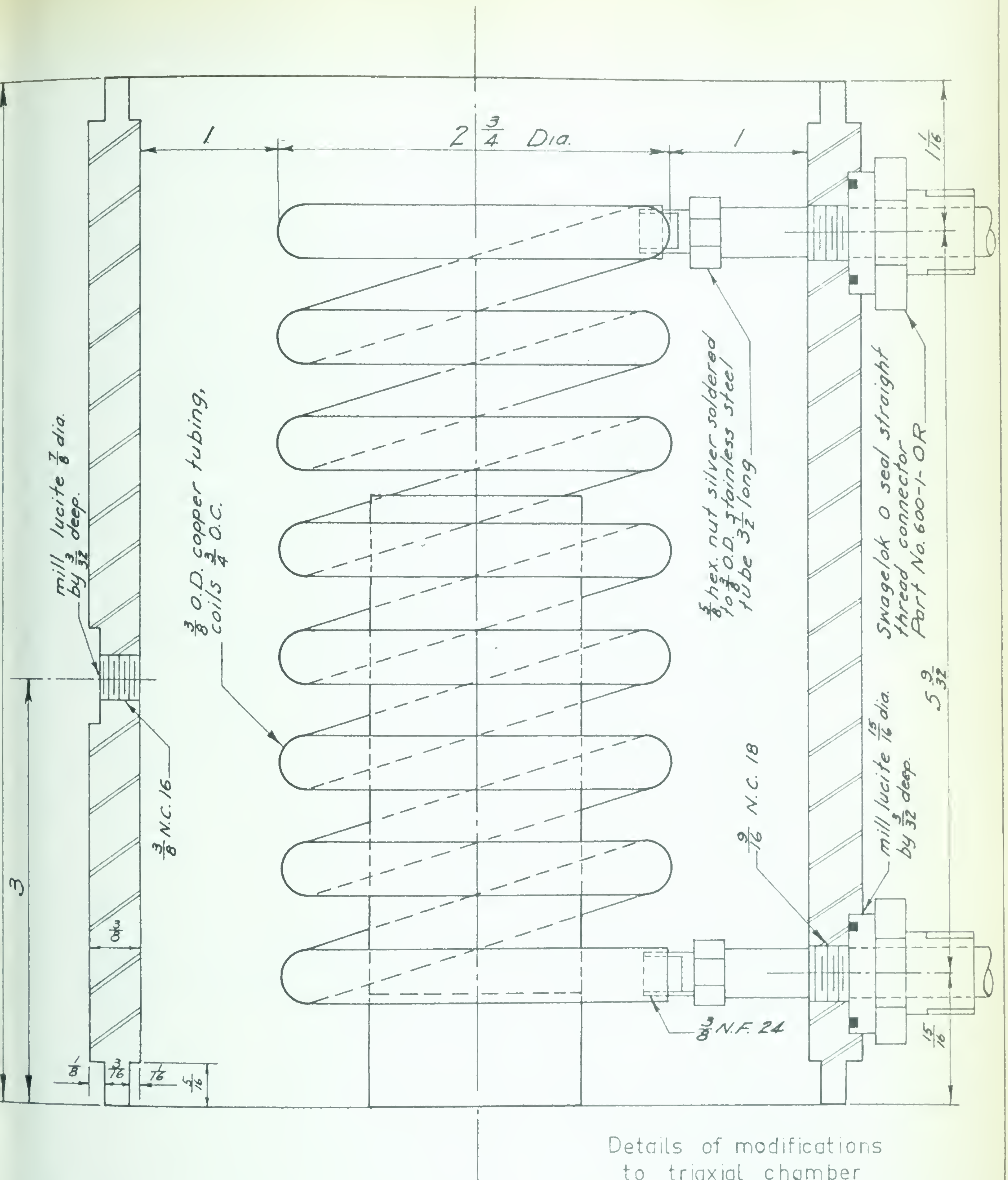
*Begin triaxial consolidation

Temperatures are for the period of consolidation only account recorder failed

Temperatures recorded with thermocouple No. 14

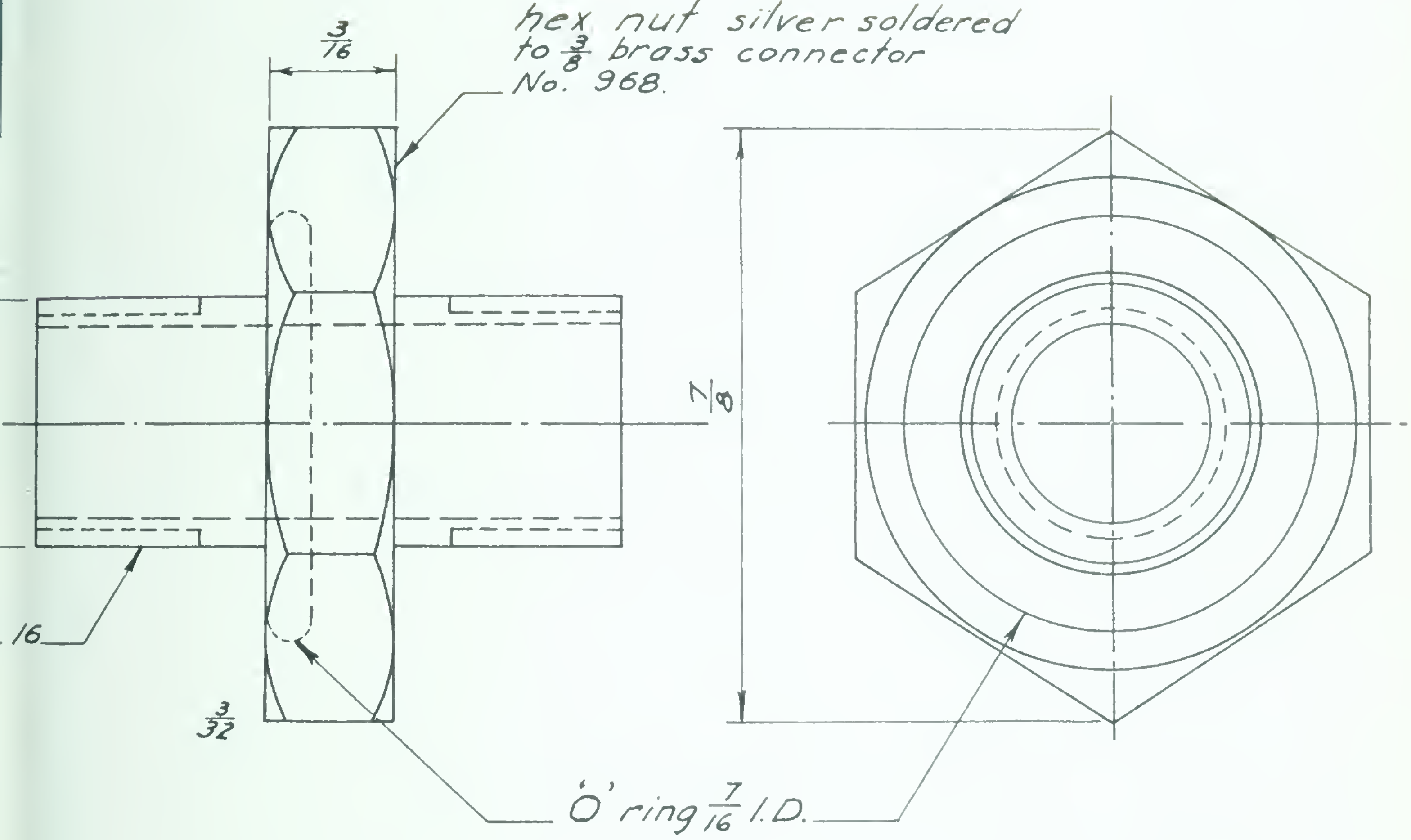
Temperatures not corrected for thermocouple calibration (-0.8°F)

APPENDIX III


1
2 3/4 Dia.
1
1 1/16
mill lucite 7/8 dia. by 3/32 deep.
3/8 O.D. copper tubing, coils 3/4 O.C.
5/8 hex. nut silver soldered to 3/8 O.D. stainless steel tube 3 1/2 long
Swagelok O seal straight thread connector Part No. 600-1-OR
5 9/32
3/8 N.C. 16
mill lucite 15/16 dia. by 3/32 deep.
9/16 N.C. 18
3
3/8
3/8 N.F. 24
15/16
1/8
3/16
1/16
5/16

Details of modifications to triaxial chamber (full size)

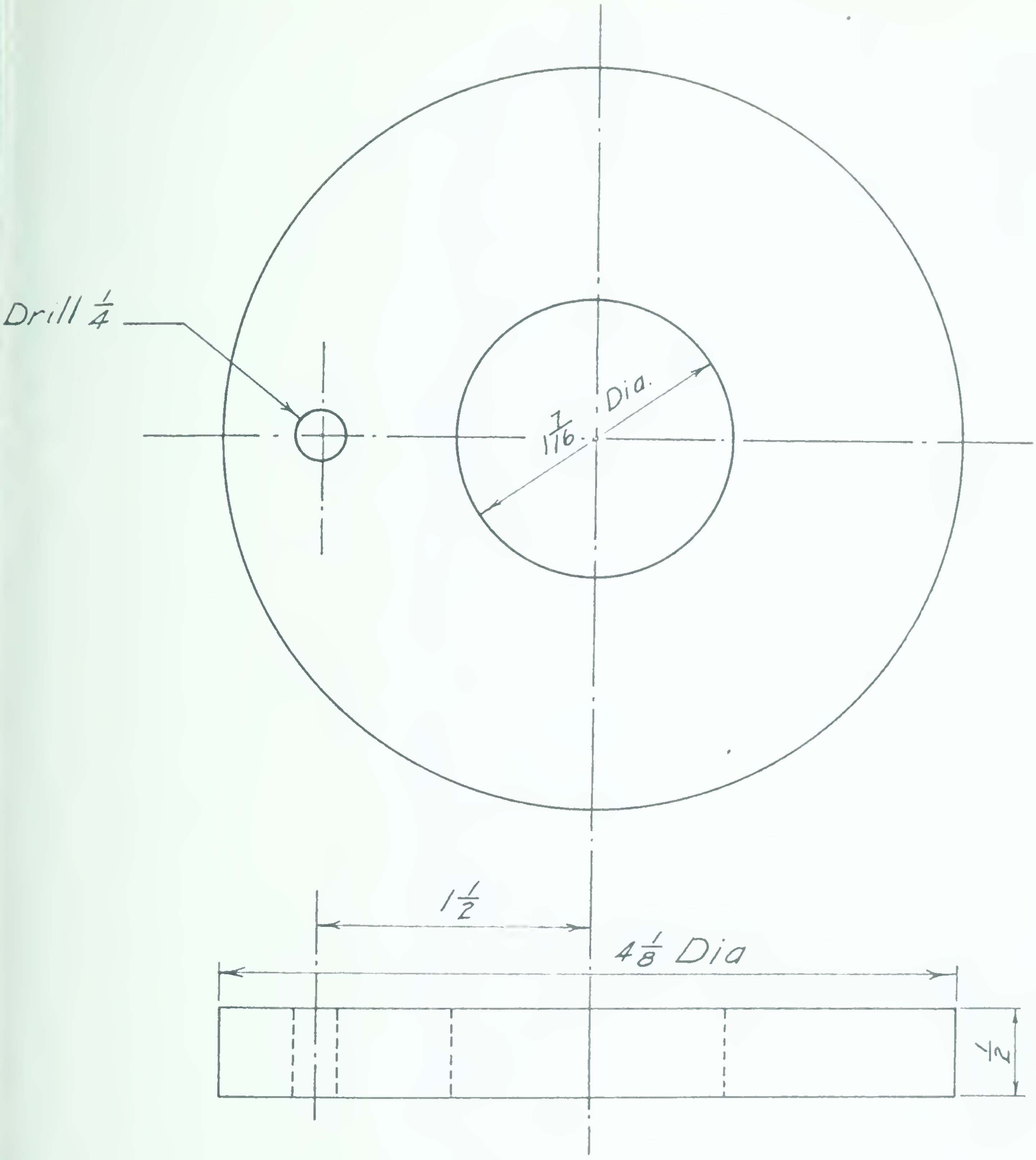
Fig. 31


hex nut silver soldered to $\frac{3}{8}$ brass connector No. 968.
$\frac{3}{16}$
$\frac{7}{8}$
16
$\frac{3}{32}$
'O' ring $\frac{7}{16}$ I.D.

Note:
thermocouple leads fed through connector and sealed with plastic filler.

Details of thermocouple connector
at triaxial cell
(3"=1")

Fig. 32



Material Lucite
3 req.

Insulation disc for
triaxial cell
(1"=1")

Fig.33

APPENDIX IV

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SOIL MECHANICS LABORATORY

SPECIFIC GRAVITY

PROJECT Thesis
SITE
SAMPLE C.H. Edmonton clay
LOCATION
HOLE DEPTH
TECHNICIAN W.S. DATE 30/10/61

mple No.	1	2
sk No.	HKW	RH
thod of Air Removal	Boiling and vacuum	Boiling and vacuum
+w+s	729.19	718.91
mperature T	23.7	23.7
+w	697.29	687.42
aporating Dish No.	S-1	S-2
. Sample Dry + Dish	192.22	190.79
re Dish	142.57	141.89
s	49.65	48.90
s	2.80	2.80

W_{b+w+s} = Weight of flask + water + sample at T°.
W_{b+w} = Weight of flask + water at T° (flask calibration curve).
W_s = Weight of dry soil
G_s = Specific gravity of soil particles $= \frac{W_s}{W_s + W_{b+w} - W_{b+w+s}}$

termination of W_s from wet soil sample:

mple No.			Sample No.		
ntainer No.			Container No.		
t. Sample Wet + Tare			Wt. Test Sample Wet + Tare		
t. Sample Dry + Tare			Tare Container		
t. Water			Wt. Test Sample Wet		
re Container			W_s		
t· of Dry Soil					
oisture Content w %					

escription of Sample: Brownish color highly plastic Edmonton clay.

emarks: Material tested is that passing # 40 sieve.
Dry weight of soil is that recovered after test.

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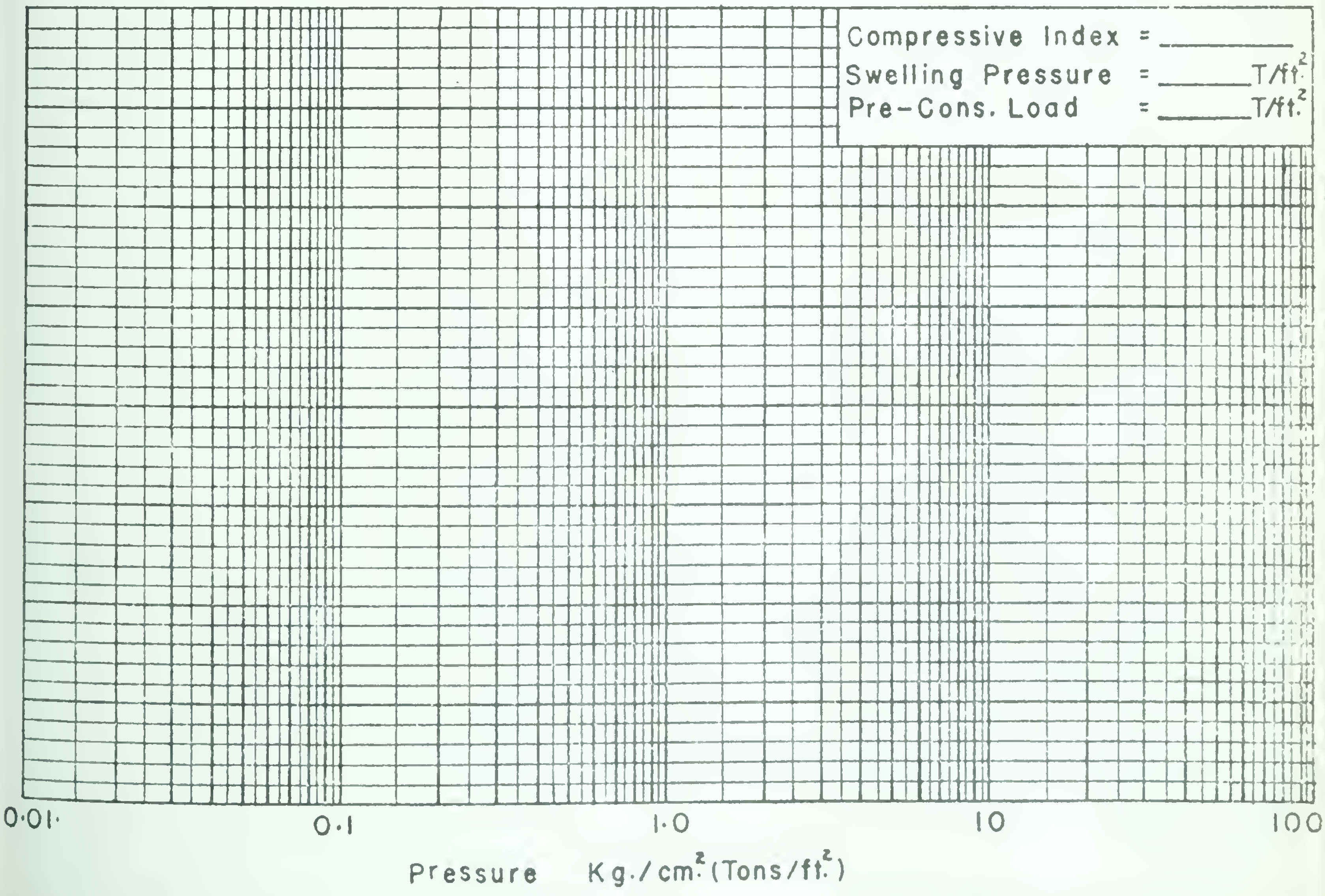
SOIL MECHANICS LABORATORY
CONSOLIDATION RESULTS

PROJECT	Thesis
SITE	
SAMPLE	C.H. Edmonton clay
LOCATION	(High temperature)
HOLE	DEPTH
TECHNICIAN W.S.	DATE 12/61

Specific Gravity of Soil Solids G_s = 2.80 Height of Soil Solids H_s = 0.308 ins.
Void Ratio e (End) = 1.001
Void Ratio e(Start) = 2.214
Void Ratio e (Start Dimensions) = 2.247

e(End) = W%(End) x G_s $H_s = \left(\frac{\text{Wt}\cdot\text{Soil}}{G_s \times \text{Area} \times 2\cdot54}\right)$ ins. e = previous e $\pm \frac{\text{Def'l.}}{H_s}$

Time nterval	Load on Pan (gms)	Corr. Dial Reading (ins.)	Deflection (ins.)	$\frac{\text{Deflection}}{H_s}$	Void Ratio e	Pressure Kg/cm² = T/ft²
7741	20	0.5144	-	-	1.001	0.07
2387	40	0.5070	0.0074	0.024	0.977	0.13
1922	160	0.4878	0.0192	0.062	0.915	0.48
1390	640	0.4605	0.0273	0.089	0.826	1.88
1590	2560	0.4339	0.0266	0.886	0.740	7.49
1381	10240	0.4170	0.0169	0.055	0.685	29.91
1353	5120	0.4551	0.0381	0.124	0.809	14.96
1529	2560	0.4962	0.0411	0.133	0.942	7.49
1337	1280	0.5440	0.0478	0.155	1.097	3.75
1510	640	0.5899	0.0459	0.149	1.246	1.88
1275	320	0.6050	0.0151	0.049	1.295	0.95
977	160	0.6151	0.0101	0.033	1.328	0.48
569	80	0.6209	0.0058	0.019	1.347	0.25
833	40	0.6231	0.0022	0.007	1.354	0.13



Compressive Index = ____
Swelling Pressure = ____ T/ft²
Pre-Cons. Load = ____ T/ft²

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SOIL MECHANICS LABORATORY

CONSOLIDATION RESULTS

PROJECT Thesis		
SITE Sheet 2		
SAMPLE		
LOCATION		
HOLE	DEPTH	
TECHNICIAN	DATE	

pecific Gravity of Soil Solids G_s = ______ Height of Soil Solids H_s = ______ ins.

oid Ratio e (End) = ______

oid Ratio e(Start) = ______

oid Ratio e (Start Dimensions) = ______

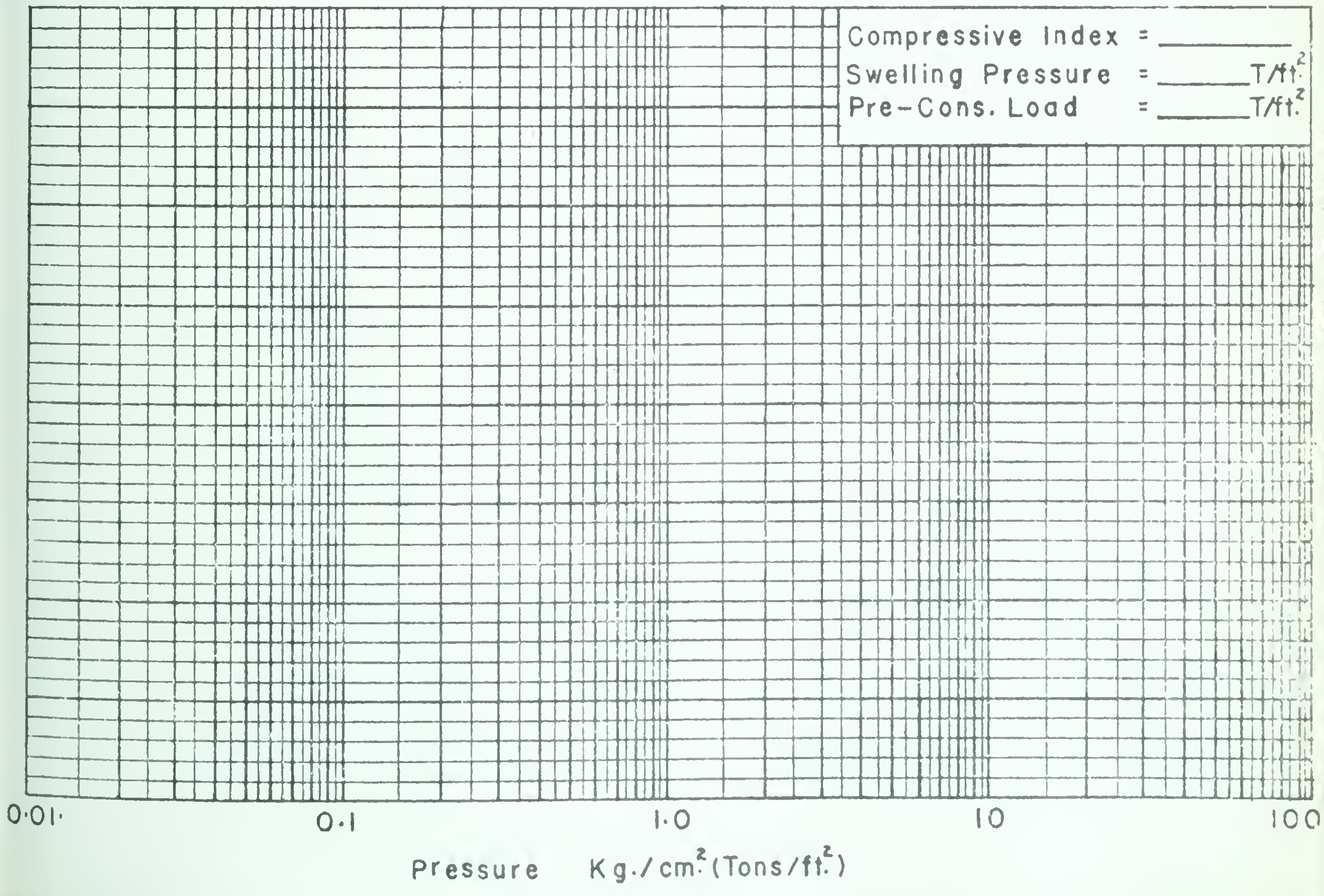
(End) = W%(End) x G_s $H_s = \left(\frac{\text{Wt. Soil}}{G_s \times \text{Area} \times 2.54}\right)$ ins. e = previous e $\pm \frac{\text{Def'l.}}{H_s}$

Time nterval	Load on Pan (gms)	Corr. Dial Reading (ins.)	Deflection (ins.)	$\frac{\text{Deflection}}{H_s}$	Void Ratio e	Pressure $Kg/cm^2 = T/ft^2$
.390	20	0.6241	0.0010	0.003	1.357	0.07
.661	40	0.6200	0.0041	0.013	1.344	0.13
.974	160	0.6056	0.0144	0.047	1.297	0.48
.531	640	0.5928	0.0128	0.042	1.255	1.88
.058	320	0.6458	0.0530	0.172	1.427	0.95
.236	160	0.6991	0.0533	0.173	1.600	0.48
.246	80	0.7449	0.0458	0.149	1.749	0.25
780	40	0.7859	0.0410	0.133	1.882	0.13
.230	20	0.8053	0.0194	0.063	1.945	0.07
	0	0.8880	0.0827	0.269	2.214	0

Compressive Index = ______

Swelling Pressure = ______ T/ft^2

Pre-Cons. Load = ______ T/ft^2



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SOIL MECHANICS LABORATORY

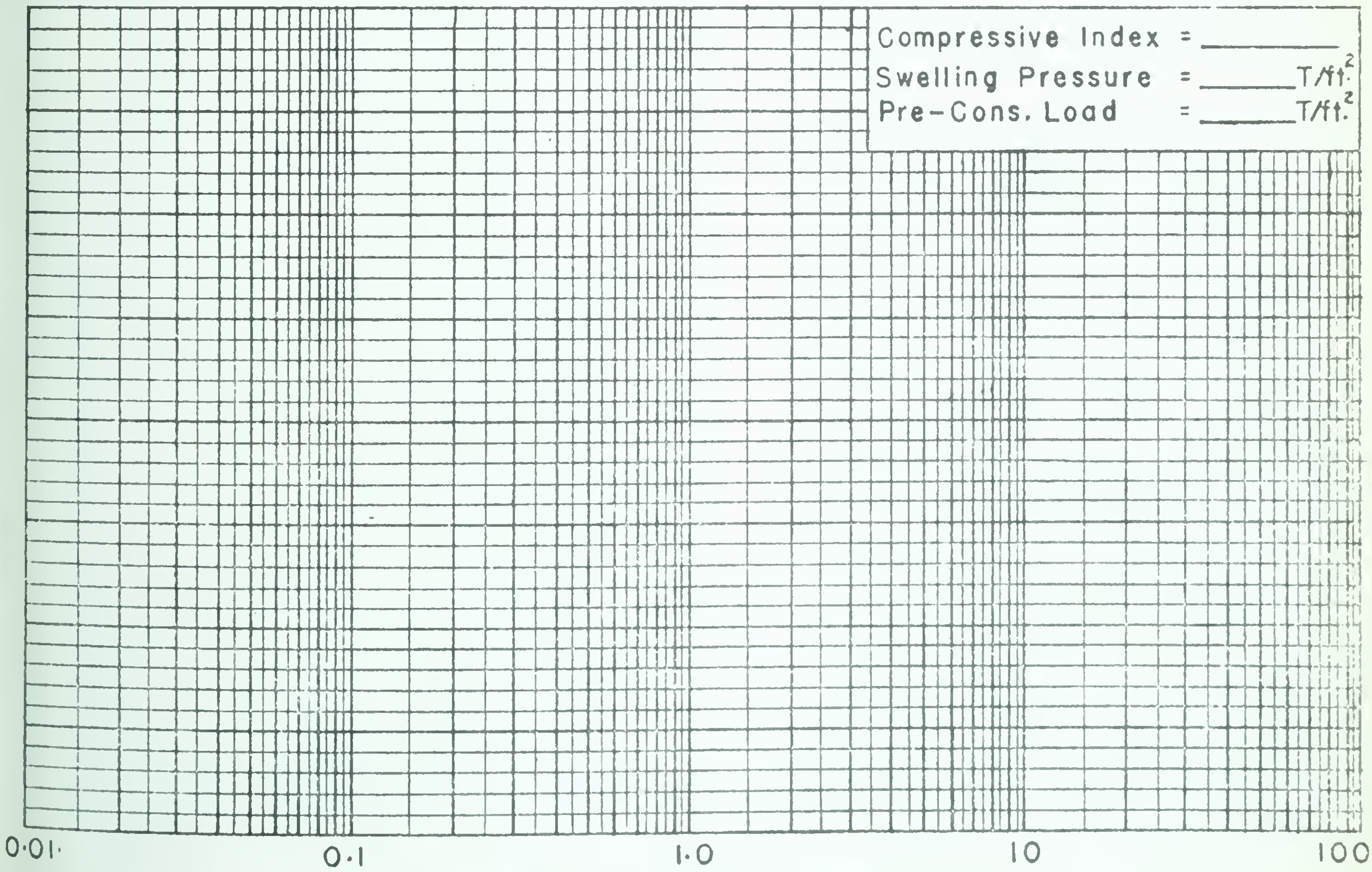
CONSOLIDATION RESULTS

PROJECT Thesis
SITE
SAMPLE C.H. Edmonton clay
LOCATION (Low Temperature)
HOLE DEPTH
TECHNICIAN W.S. DATE 12/62

Specific Gravity of Soil Solids G_s = 2.80 Height of Soil Solids H_s = 0.296 ins.
Void Ratio e (End) = 1.066
Void Ratio e(Start) = 2.296
Void Ratio e (Start Dimensions) = 2.378

e(End) = W%(End) x G_s $H_s = \left(\frac{\text{Wt. Soil}}{G_s \times \text{Area} \times 2.54}\right)$ ins. $e = \text{previous } e \pm \frac{\text{Def'l.}}{H_s}$

Time nterval	Load on Pan (gms)	Corr. Dial Reading (ins.)	Deflection (ins.)	$\frac{\text{Deflection}}{H_s}$	Void Ratio e	Pressure Kg/cm² = T/ft²
8489	20	0.5558	-	-	1.066	0.07
4360	40	0.5498	0.0060	0.0203	1.046	0.13
2860	160	0.5301	0.0197	0.0665	0.979	0.48
1540	640	0.5036	0.0265	0.0895	0.889	1.88
1300	2560	0.4781	0.0255	0.0861	0.803	7.49
1476	10240	0.4613	0.0168	0.0568	0.746	29.91
1375	5120	0.4959	0.0346	0.1169	0.863	14.96
1588	2560	0.5334	0.0375	0.1267	0.990	7.49
1348	1280	0.5762	0.0428	0.1446	1.135	3.75
1353	640	0.6151	0.0389	0.1314	1.266	1.88
1547	320	0.6327	0.0176	0.0595	1.326	0.95
1266	160	0.6450	0.0123	0.0415	1.368	0.48
1035	80	0.6531	0.0081	0.0274	1.395	0.25
600	40	0.6570	0.0039	0.0132	1.408	0.13



Compressive Index = ______
Swelling Pressure = ______ T/ft²
Pre-Cons. Load = ______ T/ft²

Pressure Kg./cm² (Tons/ft²)

UNIVERSITY of ALBERTA
DEPT. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

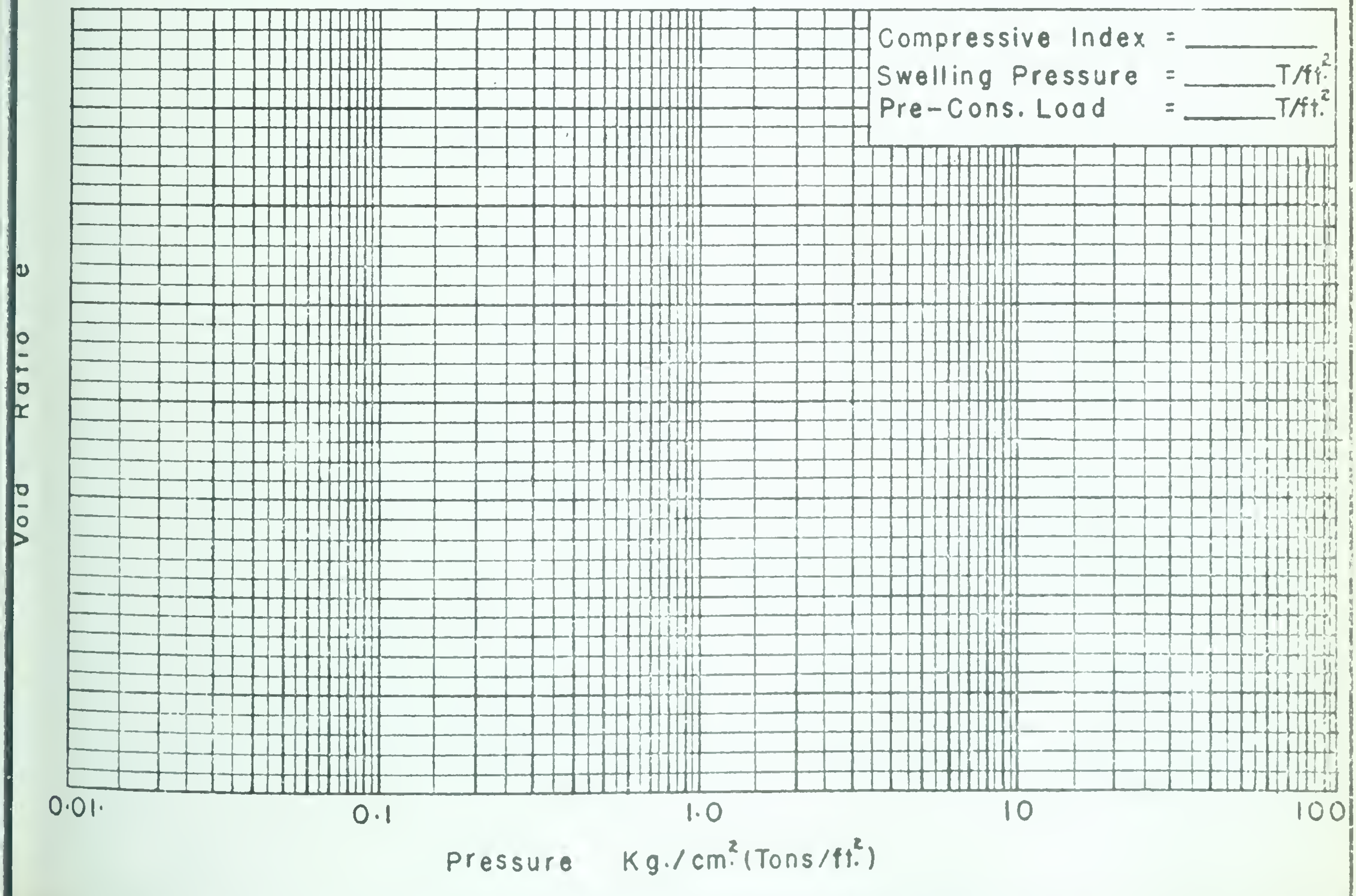
CONSOLIDATION RESULTS

PROJECT Thesis
SITE Sheet 2
SAMPLE
LOCATION
HOLE DEPTH
TECHNICIAN DATE

Specific Gravity of Soil Solids G_s = ________ Height of Soil Solids H_s = ________ ins.
Void Ratio e (End) = ________
Void Ratio e(Start) = ________
Void Ratio e (Start Dimensions) = ________

$e(End) = W\%(End) \times G_s$ $H_s = \left(\frac{Wt \cdot Soil}{G_s \times Area \times 2.54}\right)$ ins. $e = \text{previous } e \pm \frac{Def'l.}{H_s}$

Time nterval	Load on Pan (gms)	Corr. Dial Reading (ins.)	Deflection (ins.)	$\frac{Deflection}{H_s}$	Void Ratio e	Pressure Kg/cm² = T/ft²
4193	20	0.6580	0.0010	0.0034	1.411	0.07
1410	40	0.6509	0.0071	0.0240	1.387	0.13
1470	160	0.6340	0.0169	0.0571	1.330	0.48
1314	640	0.6200	0.0140	0.0473	1.283	1.88
1323	320	0.6687	0.0487	0.1645	1.448	0.95
1356	160	0.7178	0.0491	0.1659	1.614	0.48
1602	80	0.7614	0.0436	0.1473	1.761	0.25
1272	40	0.7990	0.0376	0.1270	1.888	0.13
1144	20	0.8320	0.0330	0.1115	2.000	0.07
	0	0.9200	0.0880	0.2973	2.296	0



Compressive Index = ________
Swelling Pressure = ________ T/ft²
Pre-Cons. Load = ________ T/ft²

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SOIL MECHANICS LABORATORY

ATTERBERG LIMITS

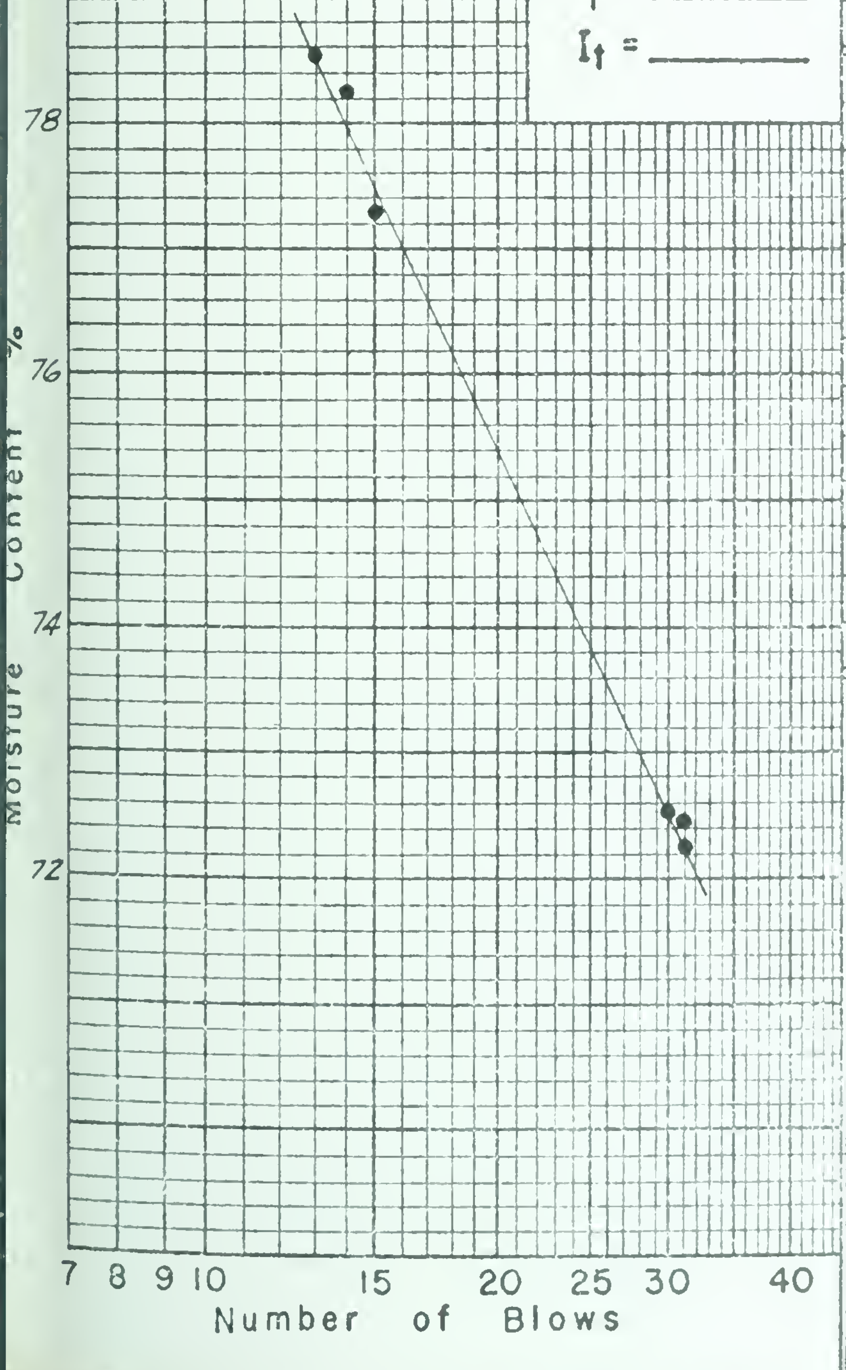
PROJECT Thesis
SITE
SAMPLE C.H. Edmonton clay
LOCATION
HOLE DEPTH
TECHNICIAN W.S. DATE 30/10/6

Liquid Limit

rial No.	1	2	3	4	5	6
o. of Blows	30	31	31	13	14	15
ontainer No.	5-7	5-8	5-9	5-10	5-11	5-12
Wt. Sample Wet + Tare	75.3640	82.0374	77.0691	75.2426	94.9606	70.9540
Wt. Sample Dry + Tare	70.9175	77.5460	71.1774	70.1383	91.0156	65.4336
Wt. Water	4.4465	4.4914	5.8917	5.1043	3.9450	5.5204
are Container	64.7878	71.3475	63.0250	63.6383	85.9741	58.2913
Wt. of Dry Soil	6.1297	6.1985	8.1524	6.5000	5.0415	7.1423
Moisture Content w%	72.54	72.46	72.27	78.53	78.25	77.29

Average Values

w_l = 73.8
w_p = 30.5
w_s =
I_p = 43.3
I_f =
I_t =



Plastic Limit

Trial No.	1	2	3
Container No.	W-4	W-5	W-6
Wt. Sample Wet + Tare	58.5256	60.5112	50.4113
Wt. Sample Dry + Tare	56.8846	58.4895	48.5510
Wt. Water	1.6410	2.0217	1.8603
Tare Container	51.5898	51.9222	42.2891
Wt. of Dry Soil	5.2948	6.5673	6.2619
Moisture Content %	30.99	30.78	29.71

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: Highly plastic brownish Edmonton clay. Grey white color in oven dry state, with very high dry strength.

Remarks: All material minus No. 40 sieve.

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ATTERBERG LIMITS

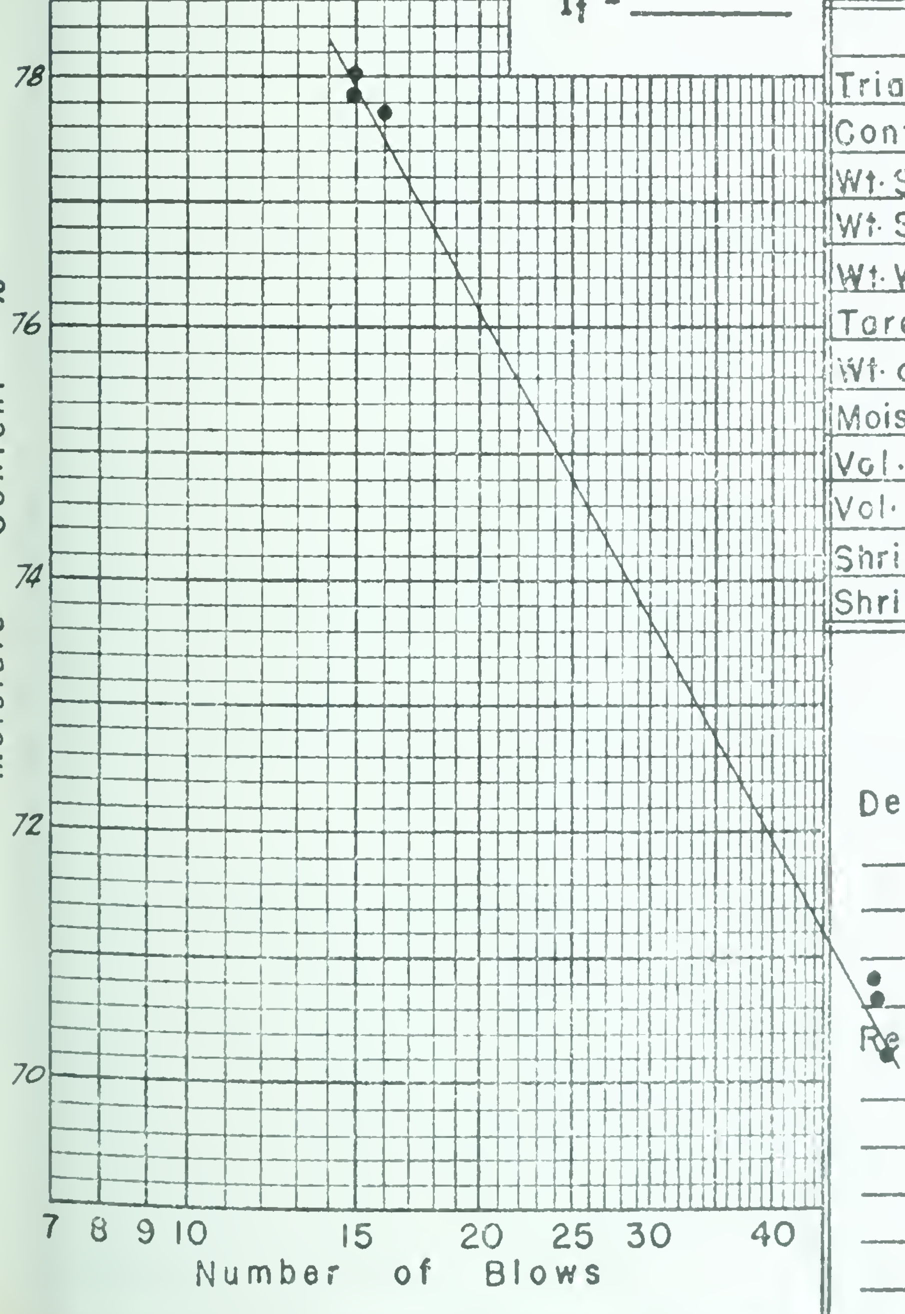
PROJECT Thesis
SITE
SAMPLE C.H. Edmonton clay
LOCATION
HOLE DEPTH
TECHNICIAN W.S. DATE 30/10/61

Liquid Limit

rial No·	1	2	3	4	5	6
o. of Blows	50	50	51	15	15	16
ontainer No.	S-1	S-2	S-3	S-4	S-5	S-6
Vt· Sample Wet + Tare	78·9460	80·4661	78·9120	76·6560	81·3306	79·3334
Vt· Sample Dry + Tare	73·7467	76·1769	73·8050	72·2156	76·6521	74·8005
Vt· Water	5·1993	4·2892	5·1070	4·4404	4·6785	4·5329
are Container	66·4090	70·1064	66·5377	66·5248	70·6406	68·9668
Vt· of Dry Soil	7·3377	6·0705	7·2673	5·6908	6·0115	5·8337
oisture Content w%	70·86	70·66	70·20	78·03	77·83	77·72

Average Values

w_l = 74·80
w_p = 31·0
w_s =
I_p = 43·8
I_f =
I_t =



Plastic Limit

Trial No·	1	2	3
Container No·	W-1	W-2	W-3
Wt· Sample Wet+Tare	48·2761	48·2725	49·1624
Wt· Sample Dry+Tare	46·1093	46·4439	47·6714
Wt· Water	2·1668	1·8286	1·4910
Tare Container	39·2867	40·4925	42·7731
Wt· of Dry Soil	6·8226	5·9514	4·8983
Moisture Content %	31·76	30·73	30·44

Shrinkage Limit

Trial No·			
Container No·			
Wt· Sample Wet + Tare			
Wt· Sample Dry + Tare			
Wt· Water			
Tare Container			
Wt· of Dry Soil W_o			
Moisture Content w%			
Vol· Container V			
Vol· Dry Soil Pat V_o			
Shrinkage Vol· $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample:

Remarks: Check test.

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HYDROMETER TEST

PROJECT Thesis
SITE
SAMPLE C.H. Edmonton clay
LOCATION
HOLE DEPTH
TECHNICIAN W.S. DATE 31/10/61

te	Temp·	Time	Elapsed Time	R'_h	$R_h = R'_h + c_m$	D m.m.	$R_h + m_t - c_d$	W.%	W % Basis Orig. Sample	Remarks
/10/61	21·8	14:50	0	30·2	30·7	0.080				
			15s.	30·1	30·6	0.051	30.94		95·6	
			30s.	30·0	30·5	0.040	30.84		95·4	
			1m	30·0	30·5	0.028	30.74		94·9	
			2m	30·0	30·5	0.021	30.74		94·9	
	21·8		4m	30·0	30·5	0.015	30·75		94·9	
	22·1		8m	30·0	30·5	0.015	30.79		95·0	
	22·1		15m	30·0	30·5	0.011	30·79		95·0	
	22·3		30m	29·2	29·7	0.008	30.03		92·7	
	22·5		1h.	27·5	28·0	0.0057	28·38		87·5	
	22·6		2h	25·0	25·5	0.0041	25·90		80·0	
	22·7		4h 10m	22·0	22·5	0.0030	22·91		70·8	
	22·9		8h 2m	18·9	19·4	0.0022	19·88		61·3	
/11/61	22·4		17h 54m	16·9	17·4	0.0015	17·78		54·8	
/11/61	22·8		32h 0m	15·0	15·5	0.0012	15·94		49·3	
/11/61	23·4		55h 40m	13·3	13·8	0.0009	14·37		44·4	
/11/61	24·0		80h 2m	12·8	13·3	0.00075	13·99		43·2	
/11/61	25·4		103h 20m	11·2	11·7	0.00065	12·73		39·4	
/11/61	26·1		126h 37m	10·0	10·5	0.00059	11·68		36·0	
/11/61	26·1		149h 50m	10·0	10·5	0.00055	11·68		36·0	

ydrometer No.s 9857R and ______ Graduate No. W-1

$\% = \frac{100}{W_s} \cdot \frac{S_s}{S_s - 1}(R_h + m_t - c_d) =$ 3.09 $(R_h + m_t - c_d)$

leniscus correction $= c_m =$ 0.5 and ______ respectively

ispersing agent used Calgon (6%) Amount 10 c.c.

orrection for change in density of liquid due to addition of dispersing agent $= c_d$

$c_d =$ 0.1 and ______ respectively

pecific Gravity of Solids $= G_s$ 2.80

escription of Sample Highly plastic brownish Edmonton clay. Grey white color in oven dry state, with very high dry strength. All material minus No. 40 sieve.

Method of Preparation ______

Remarks Computations based on material recovered after test.

Initial Moisture Content

ontainer No. ______
Vt. Sample Wet + Tare ______
Vt. Sample Dry + Tare ______
Vt. Water ______
are Container ______
Vt. of Dry Soil ______
nitial Moisture w % ______

Dry Weight of Sample

Container No. B-1
Wt. Sample (~~Wet~~/Dry) + Tare 153.89
Tare 103.49
Wt. (~~Wet~~/ Dry) Soil 50.40
Dry Weight from Initial
Moisture $= \frac{100 \times \text{Wt. Wet Soil}}{100 + \text{Init. Moist.}\%} =$ ______

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HYDROMETER TEST

PROJECT Thesis
SITE Sheet 2
SAMPLE C.H. Edmonton clay
LOCATION
HOLE DEPTH
TECHNICIAN W.S. DATE 31/10/61

ate	Temp·	Time	Elapsed Time	R'_h	$R_h = R'_h + c_m$	D m.m.	$R_h + m_t - c_d$	W.%	W % Basis Orig. Sample	Remarks
5/11/61	26·1		126h 37m	03·8	04·3	0·00039	05·39		16·7	
/11/61	26·1		149h 50m	01·0	01·5	0·00038	02·59		8·0	

ydrometer No.s 50700R and ______ Graduate No. W-1

$W\% = \frac{100}{W_s} \cdot \frac{S_s}{S_s - 1}(R_h + m_t - c_d) = $ 3.09 $(R_h + m_t - c_d)$

eniscus correction = c_m = 0.5 and ______ respectively

ispersing agent used Calgon (6%) Amount 10c.c.

orrection for change in density of liquid due to addition of dispersing agent = c_d

c_d = 0.2 and ______ respectively

pecific Gravity of Solids = G_s 2.80

escription of Sample ______

Method of Preparation ______

Remarks Fat bulb hydrometer.

Initial Moisture Content

Container No. ______
Wt. Sample Wet + Tare ______
Wt. Sample Dry + Tare ______
Wt. Water ______
Tare Container ______
Wt. of Dry Soil ______
Initial Moisture w % ______

Dry Weight of Sample

Container No. ______
Wt. Sample (Wet/Dry) + Tare ______
Tare ______
Wt. (Wet/Dry) Soil ______
Dry Weight from Initial
Moisture = $\frac{100 \times \text{Wt. Wet Soil}}{100 + \text{Init. Moist.}\%}$ = ______

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HYDROMETER TEST

PROJECT Thesis
SITE
SAMPLE C.H. Edmonton clay
LOCATION
HOLE DEPTH
TECHNICIAN W.S. DATE 31/10/61

ate	Temp·	Time	Elapsed Time	R_h'	R_h $=R_h'+c_m$	D m.m.	$R_h+m_t-c_d$	W %	W % Basis Orig. Sample	Remarks
1/10/61	22.4	15:15	0							
			15s	30.2	30.7	0.080	31.08		96.0	
			30s	30.2	30.7	0.055	31.08		96.0	
			1m	30.2	30.7	0.040	31.08		96.0	
			2m	30.2	30.7	0.028	31.08		96.0	
	22.4		4m	30.2	30.7	0.021	31.07		96.0	
	22.4		8m	30.2	30.7	0.015	31.07		96.0	
	22.5		15m	30.2	30.7	0.011	31.08		96.0	
	22.6		30m	29.2	29.7	0.0109	30.10		93.0	
	22.7		1h	27.0	27.5	0.0056	28.42		87.8	
	22.8		2h	25.5	26.0	0.0041	26.44		81.7	
	22.7		4h	22.5	23.0	0.0030	23.42		72.4	
/11/61	22.9		7h 41m	19.6	20.1	0.0022	20.58		63.4	
/11/61	22.4		18h 30m	16.9	17.4	0.0015	17.77		54.9	
/11/61	22.8		32h	15.2	15.7	0.0012	16.13		49.8	
/11/61	23.4		55h 10m	13.5	14.0	0.0009	14.58		45.0	
/11/61	24.0		79h 35m	12.8	13.3	0.00075	13.99		43.2	
5/11/61	25.4		102h 55m	11.2	11.7	0.00065	12.73		39.4	
	26.1		126h 12m	11.2	11.7	0.00060	12.89		39.8	
	26.1		149h 25m	11.8	11.5	0.00054	12.69		39.2	

Hydrometer No.s 9857R and ______ Graduate No. W-2

$W\% = \frac{100}{W_s} \cdot \frac{S_s}{S_s-1}(R_h+m_t-c_d) =$ 3.09 $(R_h+m_t-c_d)$

Meniscus correction = c_m = 0.5 and ______ respectively

Dispersing agent used Calgon (6%) Amount 10 c.c.

Correction for change in density of liquid due to addition of dispersing agent = c_d

c_d = 0.1 and ______ respectively

Specific Gravity of Solids = G_s 2.80

Description of Sample Highly plastic brownish clay. Grey white color in ovendry state, with very high dry strength. All material minus No. 40 sieve.

Method of Preparation

Remarks Check test.

Initial Moisture Content

Container No.
Wt. Sample Wet + Tare
Wt. Sample Dry + Tare
Wt. Water
Tare Container
Wt. of Dry Soil
Initial Moisture w %

Dry Weight of Sample

Container No. B-2
Wt. Sample (~~Wet~~/Dry) + Tare 185.71
Tare 135.45
Wt. (~~Wet~~/Dry) Soil 50.26
Dry Weight from Initial Moisture $= \frac{100 \times \text{Wt. Wet Soil}}{100 + \text{Init. Moist.} \%} =$

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HYDROMETER TEST

PROJECT Thesis
SITE Sheet 2
SAMPLE C.H. Edmonton clay
LOCATION
HOLE DEPTH
TECHNICIAN W.S. DATE 31/10/61

ate	Temp.	Time	Elapsed Time	R'_h	R_h $=R'_h+c_m$	D m.m.	$R_h+m_t-c_d$	W.%	W % Basis Orig. Sample	Remarks
/11/61	26.1		126h 12m	02.9	03.4	0.00042	4.49		13.9	
/11/61	26.1		149h 25m	01.0	01.5	0.00038	2.59		8.0	

ydrometer No.s 50700R and ______ Graduate No. W-2

$W\% = \frac{100}{W_s}\cdot\frac{S_s}{S_s-1}(R_h+m_t-c_d) =$ 3.09 $(R_h+m_t-c_d)$

eniscus correction $= c_m =$ 0.5 and ______ respectively

ispersing agent used Calgon (6%) Amount 10 c.c.

orrection for change in density of liquid due to addition of dispersing agent $= c_d$

$c_d =$ 0.2 and ______ respectively

pecific Gravity of Solids $= G_s$ 2.80

escription of Sample ______

Method of Preparation ______

Remarks ~~Check test.~~
Fat bulb hydrometer.

Initial Moisture Content

Container No. ______
Wt. Sample Wet + Tare ______
Wt. Sample Dry + Tare ______
Wt. Water ______
Tare Container ______
Wt. of Dry Soil ______
Initial Moisture w % ______

Dry Weight of Sample

Container No. ______
Wt. Sample (Wet/Dry) + Tare ______
Tare ______
Wt. (Wet/Dry) Soil ______
Dry Weight from Initial
Moisture $= \frac{100 \times \text{Wt. Wet Soil}}{100 + \text{Init. Moist. \%}} =$ ______

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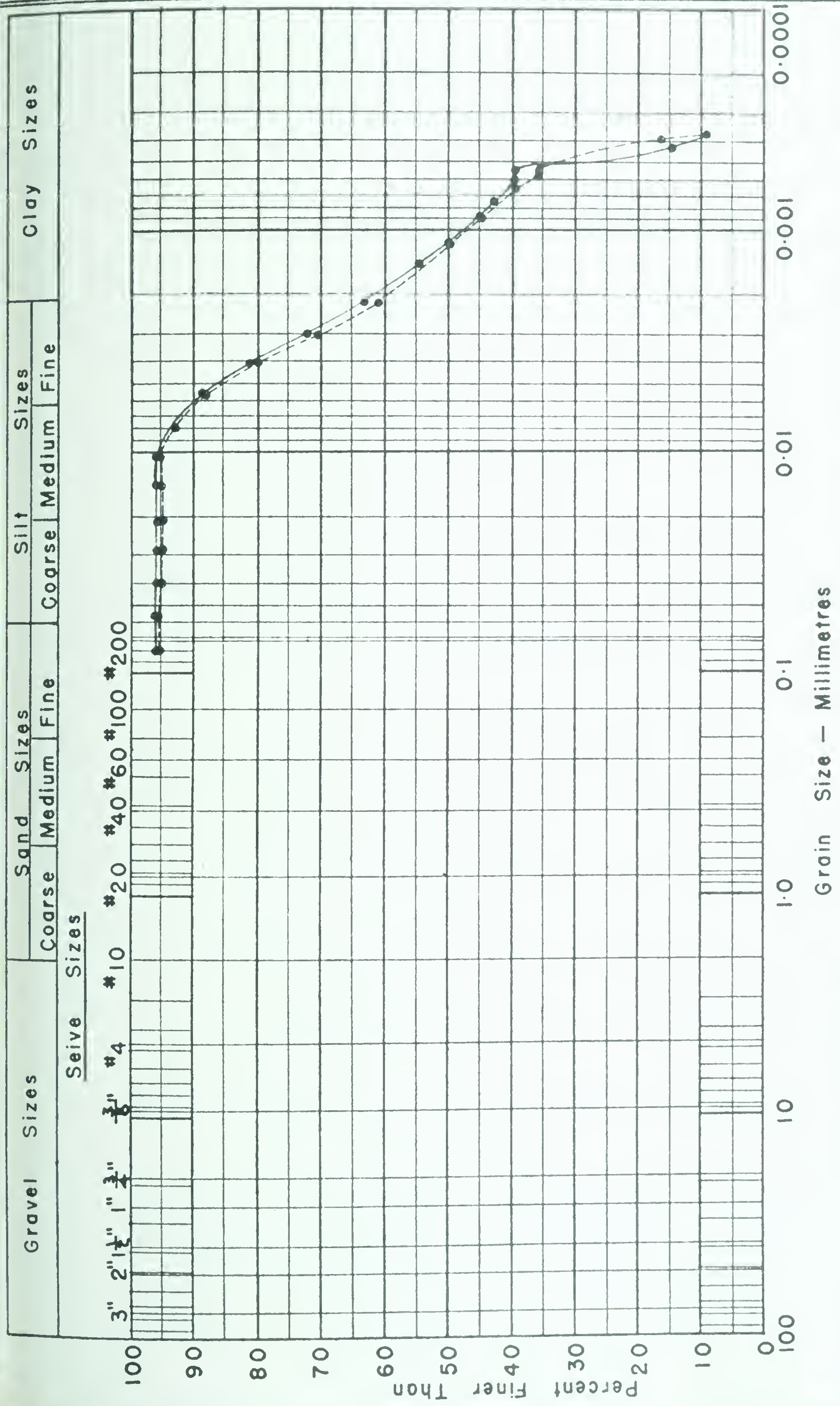
GRAIN SIZE CURVE

PROJECT	Thesis		
SITE			
SAMPLE	C.H. Edmonton clay		
LOCATION			
HOLE		DEPTH	
TECHNICIAN	W.S.	DATE	31/10/61



D_{10} = ____ mm.
D_{60} = ____ mm.
C_u ____

Remarks: Graduate W-2 ————
Graduate W-1 - - - - -

Note: M.I.T. Grain Size Scale

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SPECIFIC GRAVITY

PROJECT Thesis
SITE
SAMPLE Edmonton glacial till
LOCATION
HOLE DEPTH
TECHNICIAN W.S. DATE 15/2/62

Sample No.	1	2
Flask No.	G1	TLB
Method of Air Removal	Boiling and vacuum	Boiling and vacuum
W_{b+w+s}	732.78	734.09
Temperature T	23.1	23.4
W_{b+w}	693.88	694.95
Evaporating Dish No.	W-1	W-2
Wt. Sample Dry + Dish	193.96	206.13
Tare Dish	132.22	144.23
W_s	61.74	61.90
G_s	2.70	2.72

W_{b+w+s} = Weight of flask + water + sample at T°.
W_{b+w} = Weight of flask + water at T° (flask calibration curve).
W_s = Weight of dry soil
G_s = Specific gravity of soil particles $= \dfrac{W_s}{W_s + W_{b+w} - W_{b+w+s}}$

Determination of W_s from wet soil sample:

Sample No.			Sample No.		
Container No.			Container No.		
Wt. Sample Wet + Tare			Wt. Test Sample Wet + Tare		
Wt. Sample Dry + Tare			Tare Container		
Wt. Water			Wt. Test Sample Wet		
Tare Container			W_s		
Wt. of Dry Soil					
Moisture Content w %					

Description of Sample: Light brown colored glacial till of low plasticity.

Remarks: Material tested is that passing # 40 sieve.
Dry weight of soil is that recovered after test.

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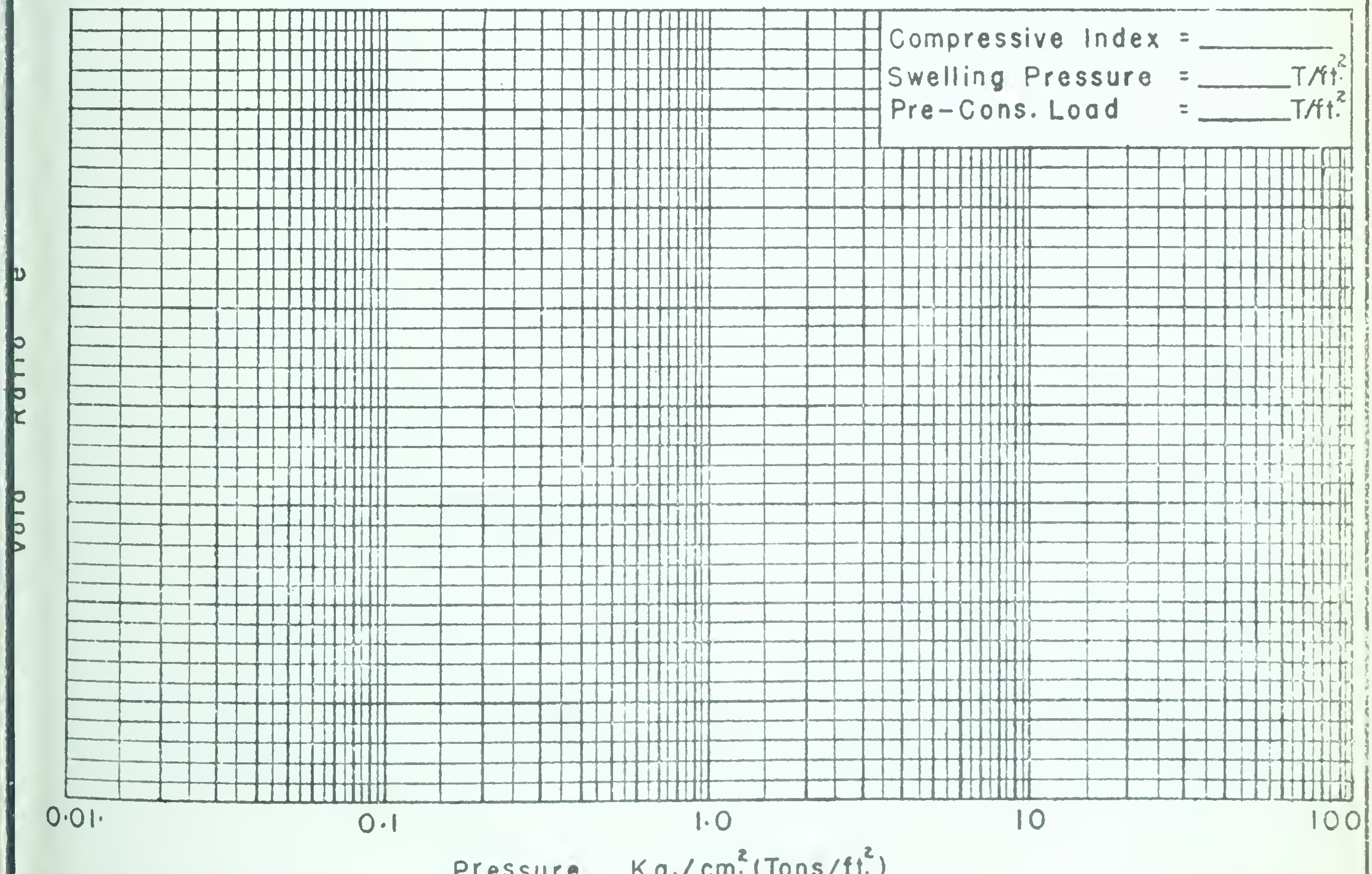
CONSOLIDATION RESULTS

PROJECT Thesis
SITE
SAMPLE Edmonton glacial till
LOCATION
HOLE DEPTH
TECHNICIAN W.S., C.D.W DATE 5/62.

Specific Gravity of Soil Solids G_s = 2.71 Height of Soil Solids H_s = 0.472 ins.
Void Ratio e (End) = 0.485
Void Ratio e(Start) = 1.086
Void Ratio e (Start Dimensions) = 1.118

e(End) = W%(End) x G_s $H_s = \left(\frac{\text{Wt. Soil}}{G_s \times \text{Area} \times 2.54}\right)$ ins. $e = \text{previous } e \pm \frac{\text{Def'l.}}{H_s}$

Time Interval	Load on Pan (gms)	Corr. Dial Reading (ins.)	Deflection (ins.)	Deflection / H_s	Void Ratio e	Pressure Kg/cm^2 = T/ft^2
1450	20	0.7011	-	-	0.485	0.07
1440	40	0.6957	0.0054	0.011	0.474	0.13
5760	160	0.6850	0.0107	0.026	0.448	0.48
1440	640	0.6679	0.0171	0.036	0.412	1.88
1440	2560	0.6540	0.0139	0.029	0.383	7.49
1440	10240	0.6469	0.0071	0.015	0.368	29.91
1440	5120	0.6774	0.0305	0.065	0.433	14.96
4305	2560	0.7079	0.0305	0.065	0.498	7.49
1440	1280	0.7421	0.0342	0.073	0.571	3.75
1440	640	0.7790	0.0369	0.078	0.649	1.88
1440	320	0.8153	0.0363	0.077	0.726	0.95
1440	160	0.8540	0.0387	0.082	0.808	0.48
5655	80	0.8855	0.0315	0.067	0.875	0.25
1495	40	0.9148	0.0293	0.062	0.937	0.13



Compressive Index = ______
Swelling Pressure = ______ T/ft^2
Pre-Cons. Load = ______ T/ft^2

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CONSOLIDATION RESULTS

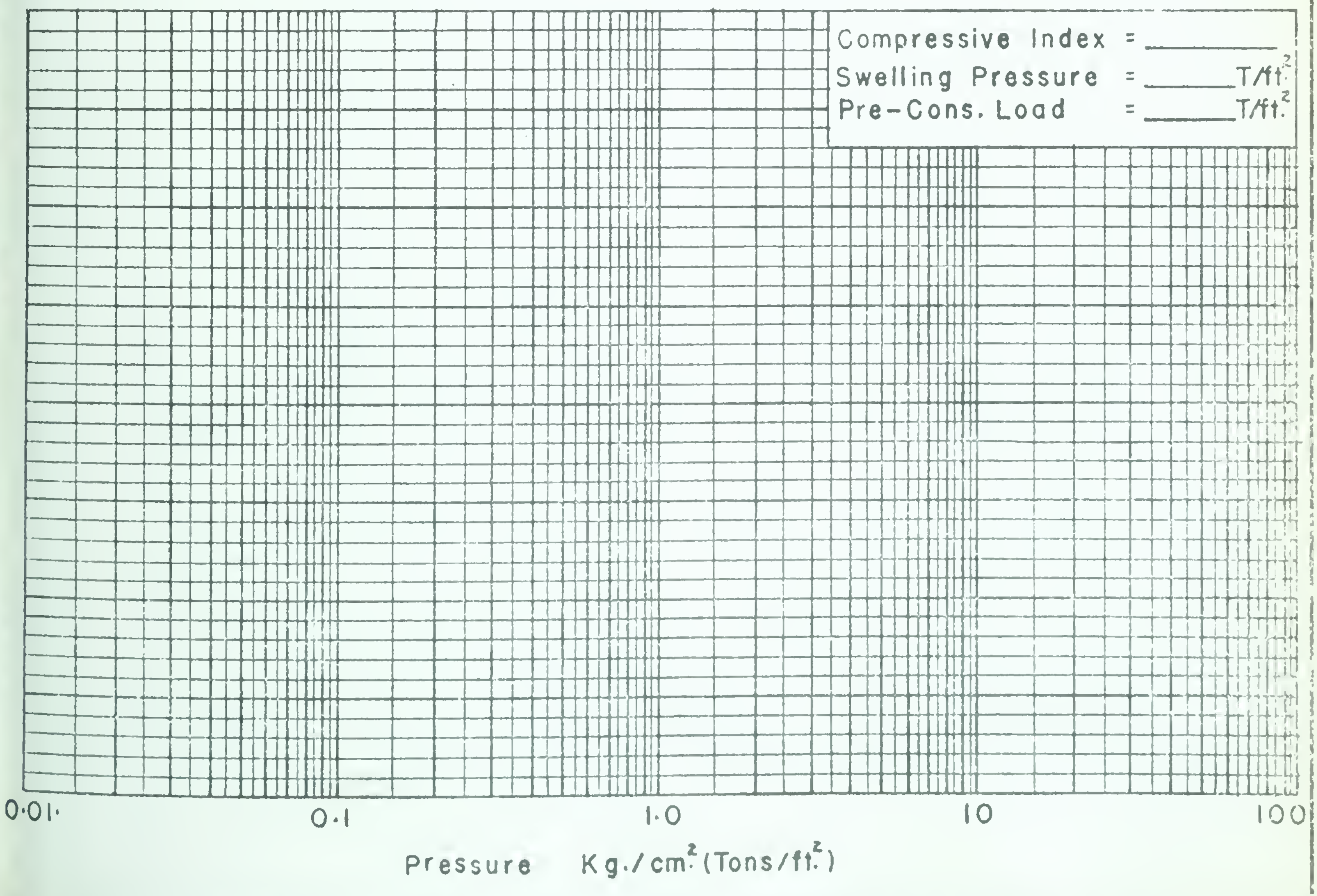
PROJECT Thesis
SITE Sheet 2
SAMPLE
LOCATION
HOLE DEPTH
TECHNICIAN DATE

Specific Gravity of Soil Solids G_s = ________ Height of Soil Solids H_s = ________ ins.
Void Ratio e (End) = ________
Void Ratio e(Start) = ________
Void Ratio e (Start Dimensions) = ________

e(End) = W%(End) x G_s $H_s = \left(\frac{\text{Wt. Soil}}{G_s \times \text{Area} \times 2.54}\right)$ ins. e = previous e $\pm \frac{\text{Def'l.}}{H_s}$

Time nterval	Load on Pan (gms)	Corr. Dial Reading (ins.)	Deflection (ins.)	$\frac{\text{Deflection}}{H_s}$	Void Ratio e	Pressure Kg/cm² = T/ft²
1289	20	0.9337	0.0189	0.040	0.977	0.07
	0	0.9846	0.0509	0.108	1.085	0

Compressive Index = ________
Swelling Pressure = ______ T/ft²
Pre-Cons. Load = ______ T/ft²



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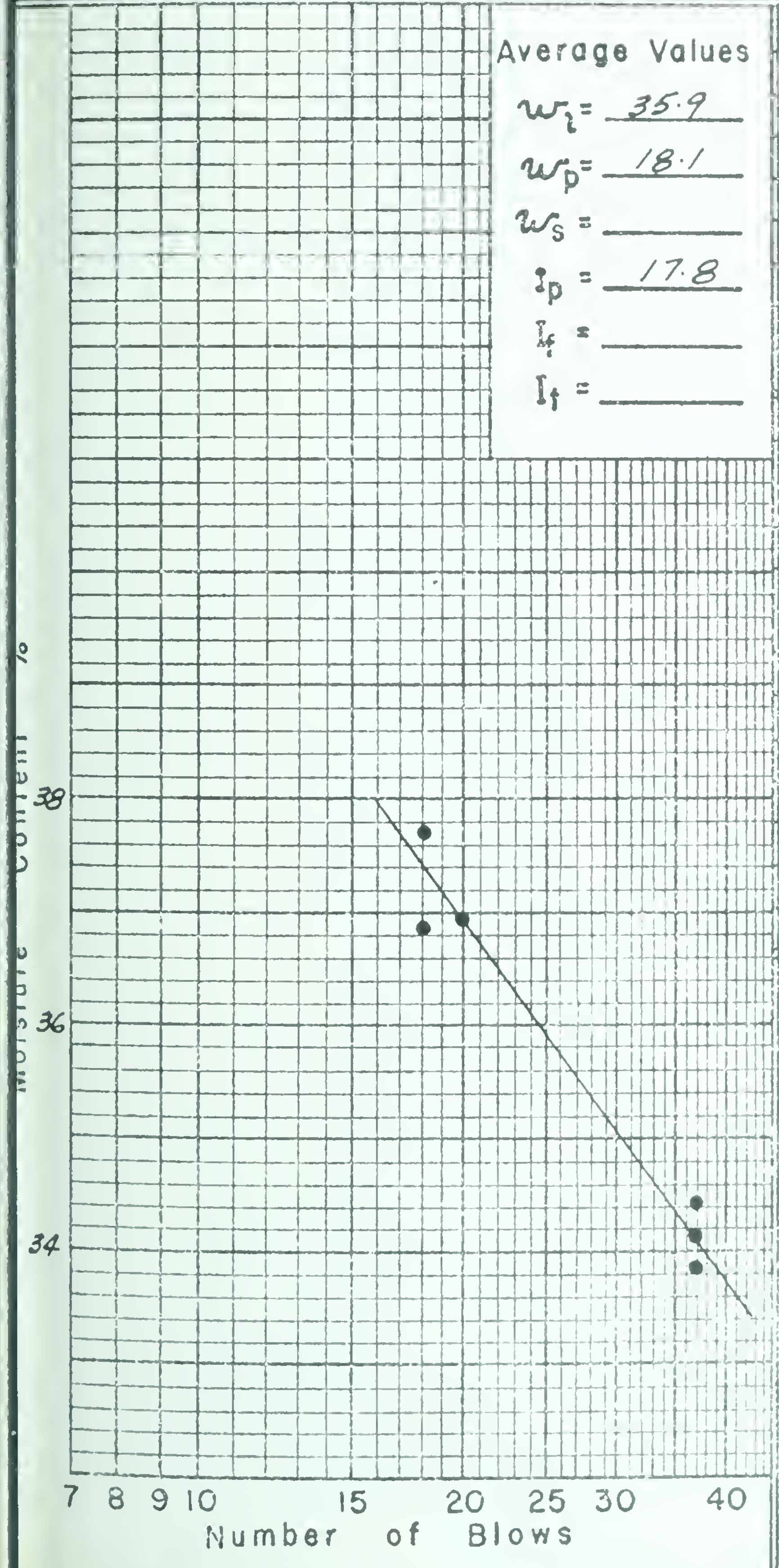
SOIL MECHANICS LABORATORY

ATTERBERG LIMITS

PROJECT Thesis
SITE
SAMPLE Edmonton till
LOCATION
HOLE DEPTH
TECHNICIAN W.S. DATE 12/2/62

Liquid Limit

rial No·	1	2	3	4	5	6
o. of Blows	37	37	37	18	18	20
ontainer No.	5-4	5-5	5-6	5-7	5-8	5-9
Vt· Sample Wet + Tare	76·3911	80·0694	80·8759	83·3913	70·1278	78·7413
Vt· Sample Dry + Tare	73·8929	77·6676	77·8418	80·0853	67·0632	74·9532
Vt· Water	2·4982	2·4018	3·0341	3·3060	3·0646	3·7881
are Container	66·5254	70·6403	68·9675	71·3302	58·7407	64·6934
Vt· of Dry Soil	7·3675	7·0273	8·8743	8·7551	8·3225	10·2598
oisture Content w%	33·86	34·18	34·45	37·76	36·82	36·92



Average Values
w_l = 35·9
w_p = 18·1
w_s =
I_p = 17·8
I_f =
I_t =

Plastic Limit

Trial No·	1	2	3
Container No·	W-6	W-12	W-13
Wt· Sample Wet+Tare	47·0204	44·1456	49·2750
Wt· Sample Dry+Tare	46·2941	43·5241	48·4842
Wt· Water	0·7263	0·6215	0·7908
Tare Container	42·2912	40·0787	44·1311
Wt· of Dry Soil	4·0029	3·4454	4·3531
Moisture Content %	18·14	18·04	18·17

Shrinkage Limit

Trial No·			
Container No·			
Wt· Sample Wet + Tare			
Wt· Sample Dry + Tare			
Wt· Water			
Tare Container			
Wt· of Dry Soil W_o			
Moisture Content w%			
Vol· Container V			
Vol· Dry Soil Pat V_o			
Shrinkage Vol· $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w - \left(\frac{V-V_o}{W_o} \times 100\right)$$

Description of Sample: Light brown colored glacial till.

Remarks: All material minus No. 40 sieve.

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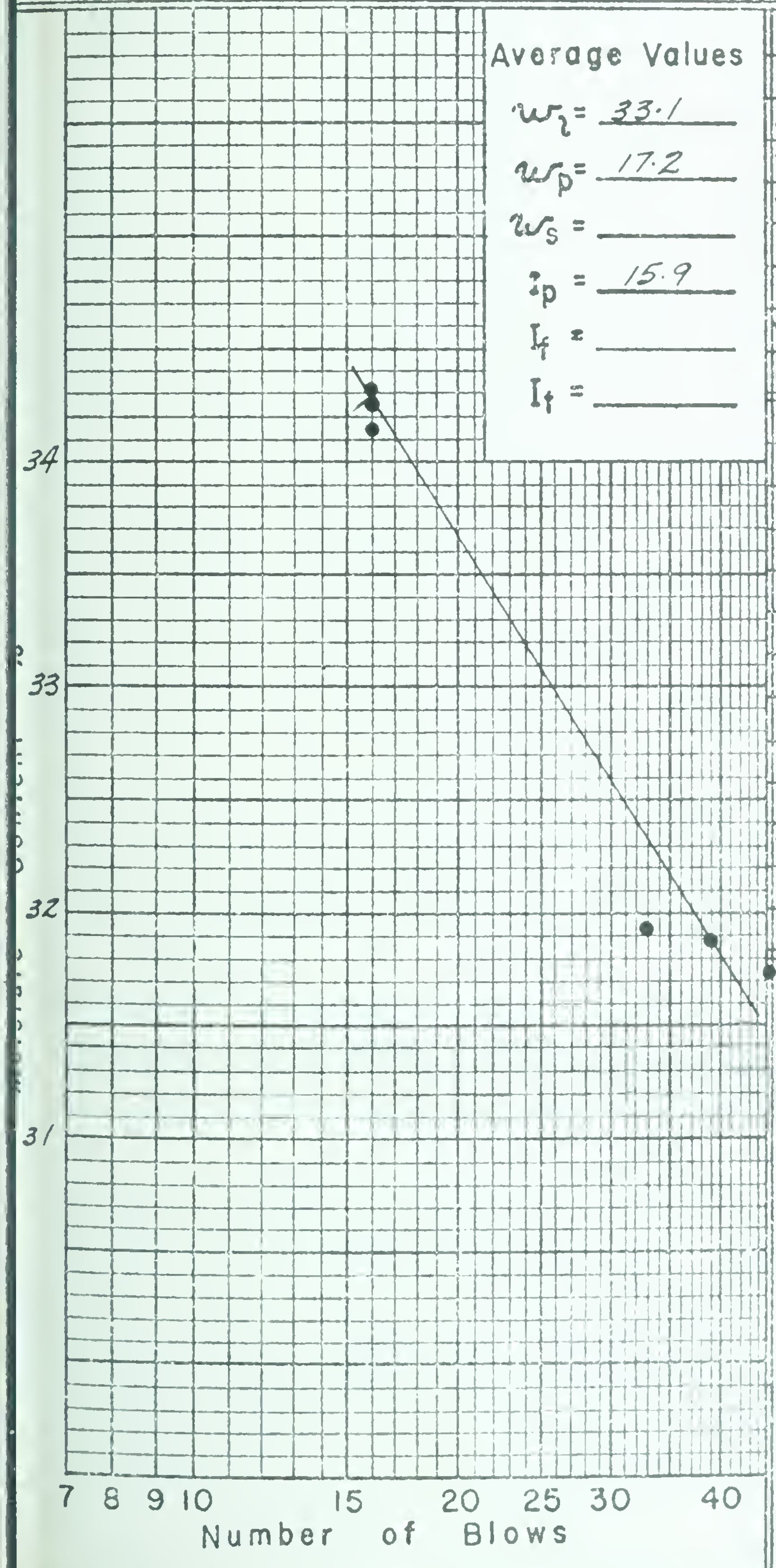
ATTERBERG LIMITS

PROJECT	Thesis		
SITE			
SAMPLE	Edmonton till		
LOCATION			
HOLE		DEPTH	
TECHNICIAN	W.S.	DATE	28/2/62

Liquid Limit

ial No.	1	2	3	4	5	6
o. of Blows	16	16	16	33	39	45
ontainer No.	5-4	5-6	5-6	5-20	5-21	5-22
t· Sample Wet + Tare	78·9005	85·6294	85·6983	80·8292	70·1000	78·2873
t· Sample Dry + Tare	75·7378	81·8034	81·4392	78·5301	67·3522	74·6722
t· Water	3·1627	3·8260	4·2591	2·2991	2·7478	3·6151
are Container	66·5231	70·6381	68·9656	71·3278	58·7382	63·2890
t· of Dry Soil	9·2147	11·1653	12·4736	7·2023	8·6140	11·3832
oisture Content w%	34·32	34·27	34·15	31·92	31·89	31·76

Average Values
w_l = 33·1
w_p = 17·2
w_s =
I_p = 15·9
I_f =
I_t =



Plastic Limit

Trial No.	1	2	3
Container No.	W-6	W-12	W-13
Wt· Sample Wet + Tare	48·0870	45·3740	50·8230
Wt· Sample Dry + Tare	47·2194	44·6018	49·8544
Wt· Water	0·8676	0·7722	0·9686
Tare Container	42·2883	40·0740	44·1271
Wt· of Dry Soil	4·9311	4·5278	5·7273
Moisture Content %	17·59	17·05	16·91

Shrinkage Limit

Trial No.			
Container No.			
Wt· Sample Wet + Tare			
Wt· Sample Dry + Tare			
Wt· Water			
Tare Container			
Wt· of Dry Soil W_o			
Moisture Content w%			
Vol· Container V			
Vol· Dry Soil Pat V_o			
Shrinkage Vol· $V-V_o$			
Shrinkage Limit w_s			

$$w_s = w\left(\frac{V-V_o}{W_o}\times 100\right)$$

Description of Sample:

Remarks: Check test.

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HYDROMETER TEST

PROJECT Thesis
SITE
SAMPLE Edmonton till
LOCATION
HOLE DEPTH
TECHNICIAN W.S. DATE 15/2/62

ate	Temp·	Time	Elapsed Time	R'_h	$R_h = R'_h + c_m$	D m.m.	$R_h+m_t-c_d$	W %	W % Basis Orig. Sample	Remarks
/2/62	25·2	15:00	65	20·0	20·3	0·15	20·9		65·6	
			155	19·2	19·5	0·091	20·1		63·1	
			305	18·3	18·6	0·066	19·2		60·3	
			1m	17·0	17·3	0·048	17·9		56·2	
			2	15·9	16·2	0·035	16·8		52·8	
			4	14·9	15·2	0·024	15·8		49·6	
	25·2		8	14·0	14·3	0·017	14·9		46·8	
	24·9		15	13·0	13·3	0·013	13·8		43·4	
	24·9		30	12·2	12·5	0·0094	13·0		40·8	
	24·7		60	11·2	11·5	0·0067	12·0		37·6	
	24·4		120	10·1	10·4	0·0048	10·8		33·9	
	24·0		240	8·6	8·9	0·0035	9·2		28·9	
	23·7		480	7·8	8·1	0·0025	8·4		26·4	
/2/62	23·7		1360	6·2	6·5	0·0015	6·8		21·4	
/2/62	23·5		1965	5·9	6·2	0·0013	6·4		20·0	
7/2/62	24·1		3306	5·0	5·3	0·0010	5·6		17·5	
/2/62	23·7		4705	4·8	5·1	0·00083	5·3		16·6	
/2/62	24·0		7144	3·9	4·2	0·00071	4·5		14·1	

ydrometer No.s 1746A and ______ Graduate No. S-2

$\% = \frac{100}{W_s}\cdot\frac{S_s}{S_s-1}(R_h+m_t-c_d) =$ 3.14 $(R_h+m_t-c_d)$

eniscus correction = c_m = 0.3 and ______ respectively

ispersing agent used Calgon (6%) Amount 10 c.c.

orrection for change in density of liquid due to addition of dispersing agent = c_d

c_d = 0.5 and ______ respectively

pecific Gravity of Solids = G_s 2.71

escription of Sample Light brown colored glacial till of low plasticity.
Material used was that finer than No. 40 sieve size.

Method of Preparation

Remarks Computations based on material recovered after test.

Initial Moisture Content

ontainer No.
Vt. Sample Wet + Tare
Vt. Sample Dry + Tare
Vt. Water
are Container
Vt. of Dry Soil
nitial Moisture w %

Dry Weight of Sample

Container No. S-2
Wt. Sample (~~Wet~~/Dry) + Tare 182.98
Tare 132.59
Wt. (~~Wet~~/Dry) Soil 50.39
Dry Weight from Initial Moisture = $\frac{100 \times \text{Wt. Wet Soil}}{100 + \text{Init. Moist. \%}}$ =

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HYDROMETER TEST

PROJECT Thesis
SITE Sheet 2
SAMPLE Edmonton till
LOCATION
HOLE DEPTH
TECHNICIAN W.S. DATE 15/2/62

ate	Temp·	Time	Elapsed Time	R'_h	$R_h = R'_h + c_m$	D m.m.	$R_h + m_t - c_d$	W.%	W % Basis Orig. Sample	Remarks
5/2/62	24·7		60 m.	9·8	10·0	0·0038	10·6		33·3	
	24·4		120	8·8	9·0	0·0028	9·5		29·8	
	24·0		240	7·9	8·1	0·0021	8·6		27·0	
	23·7		480	7·0	7·2	0·0015	7·6		23·8	
	23·7		1360	5·3	5·5	0·00095	5·9		18·5	
	23·5		1965	5·0	5·2	0·00080	5·5		17·3	
	24·1		3306	4·8	5·0	0·00063	5·4		16·9	
	23·7		4705	4·5	4·7	0·00053	5·1		16·0	
	24·0		7144	3·9	4·1	0·00044	4·5		14·1	

ydrometer No.s 5478T and Graduate No. S-2

$W\% = \frac{100}{W_s} \cdot \frac{S_s}{S_s - 1} (R_h + m_t - c_d) =$ 3.14 $(R_h + m_t - c_d)$

eniscus correction = c_m = 0.2 and respectively

ispersing agent used Calgon (6%) Amount 10 c.c.

orrection for change in density of liquid due to addition of dispersing agent = c_d

c_d = 0.4 and respectively

pecific Gravity of Solids = G_s 2.71

escription of Sample

Method of Preparation

Remarks Fat bulb hydrometer

Initial Moisture Content

ontainer No.
Wt. Sample Wet + Tare
Wt. Sample Dry + Tare
Wt. Water
are Container
Wt. of Dry Soil
nitial Moisture w %

Dry Weight of Sample

Container No.
Wt. Sample (Wet/Dry) + Tare
Tare
Wt. (Wet/Dry) Soil
Dry Weight from Initial Moisture = $\frac{100 \times \text{Wt. Wet Soil}}{100 + \text{Init. Moist. \%}}$ =

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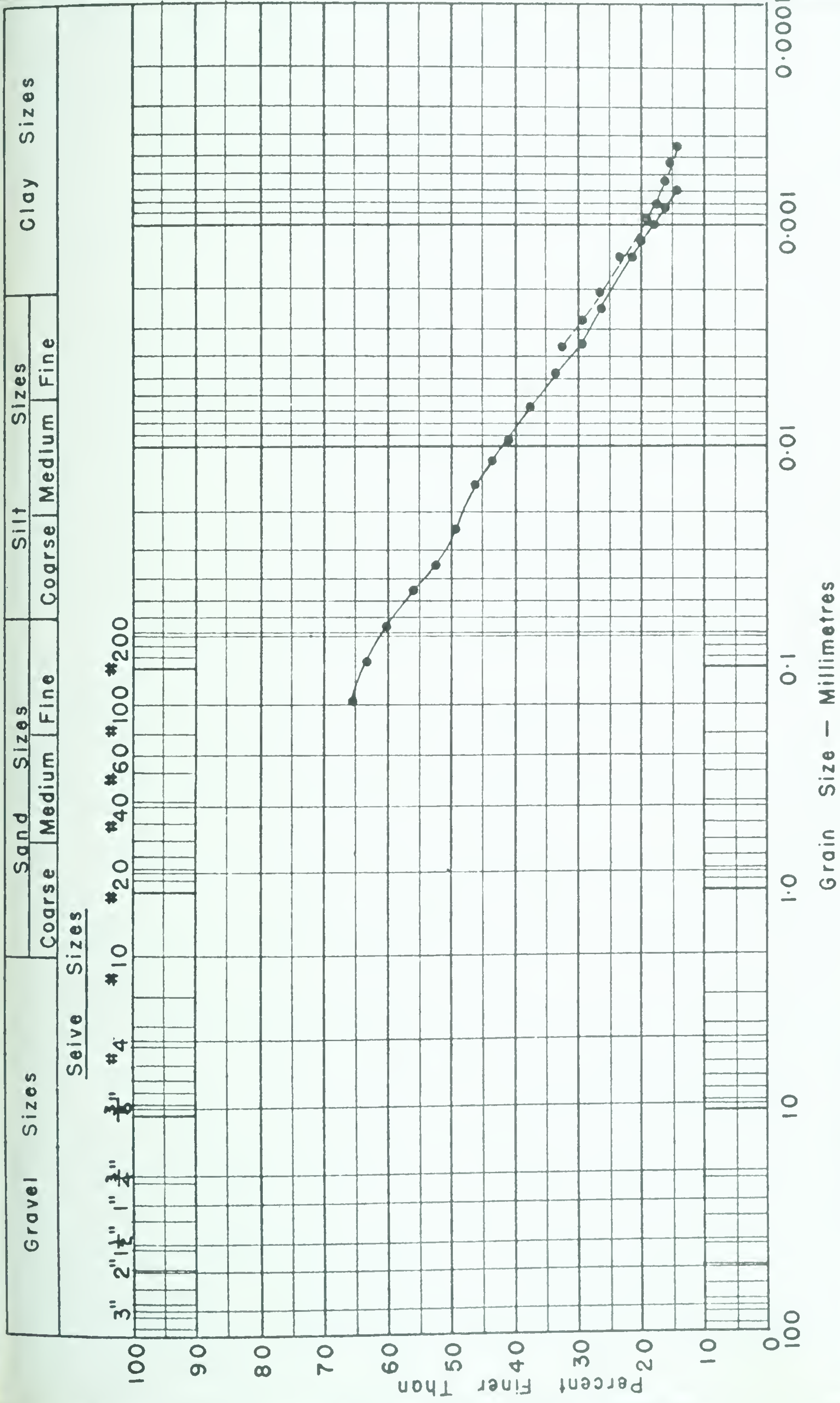
GRAIN SIZE CURVE

PROJECT	Thesis		
SITE	Edmonton till		
SAMPLE			
LOCATION			
HOLE		DEPTH	
TECHNICIAN	W.S.	DATE	15/2/62



D_{10} = ——— mm.
D_{60} = ——— mm.
C_U ———

Remarks: Graduate S-2
Slim bulb readings ————
Fat bulb readings - - - - -

Note: M.I.T. Grain Size Scale

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HYDROMETER TEST

PROJECT Thesis
SITE
SAMPLE Edmonton till
LOCATION
HOLE DEPTH
TECHNICIAN W.S. DATE 15/2/62

ate	Temp.	Time	Elapsed Time	R_h'	$R_h = R_h' + c_m$	D m.m.	$R_h+m_t-c_d$	W %	W % Basis Orig. Sample	Remarks
/2/62	24.9	15:27	6s	20.1	20.4	0.15	20.9		65.6	
			15s	19.2	19.5	0.094	20.0		62.8	
			30s	17.9	18.2	0.067	18.7		58.7	
			1m	16.8	17.1	0.047	17.6		55.3	
			2	15.4	15.7	0.035	16.2		50.9	
	24.9		4	14.6	14.9	0.025	15.4		48.4	
	24.8		8	13.8	14.1	0.018	14.6		45.8	
	24.8		15	12.9	13.2	0.013	13.7		43.0	
	24.7		30	12.0	12.3	0.0095	12.9		40.5	
	24.5		60	11.0	11.3	0.0067	11.7		36.7	
	24.3		120	9.8	10.1	0.0048	10.5		33.0	
	23.9		240	8.7	9.0	0.0035	9.3		29.2	
	23.7		429	7.7	8.0	0.0026	8.2		25.7	
/2/62	23.7		1333	6.2	6.5	0.0015	6.7		21.0	
	23.5		1965	5.6	5.9	0.0013	6.2		19.5	
/2/62	24.1		3306	4.9	5.2	0.0010	5.5		17.3	
/2/62	23.7		4705	4.4	4.7	0.00084	4.9		15.4	
/2/62	24.0		7144	3.9	4.2	0.00070	4.5		14.1	

ydrometer No.s 1746A and ______ Graduate No. S-1

$\% = \frac{100}{W_s}\cdot\frac{S_s}{S_s-1}(R_h+m_t-c_d) = 3.14\ (R_h+m_t-c_d)$

eniscus correction = c_m = 0.3 and ______ respectively

ispersing agent used Calgon (6%) Amount 10c.c.

orrection for change in density of liquid due to addition of dispersing agent = c_d

c_d = 0.5 and ______ respectively

pecific Gravity of Solids = G_s 2.71

escription of Sample Light brown colored glacial till of low plasticity.
Material used was that finer than No. 40 sieve size.

Method of Preparation

Remarks Computations based on material recovered after test. Check test.

Initial Moisture Content

ontainer No.
Vt. Sample Wet + Tare
Vt. Sample Dry + Tare
Vt. Water
are Container
Vt. of Dry Soil
nitial Moisture w %

Dry Weight of Sample

Container No. S-1
Wt. Sample (Wet/Dry) + Tare 161.24
Tare 110.77
Wt. (Wet/Dry) Soil 50.47
Dry Weight from Initial Moisture = $\frac{100 \times \text{Wt. Wet Soil}}{100 + \text{Init. Moist. \%}}$ =

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HYDROMETER TEST

PROJECT Thesis
SITE Sheet 2
SAMPLE Edmonton till
LOCATION
HOLE DEPTH
TECHNICIAN W.S. DATE 15/2/62

Date	Temp.	Time	Elapsed Time	R_h'	$R_h = R_h' + c_m$	D m.m.	$R_h + m_t - c_d$	W.%	W % Basis Orig. Sample	Remarks
15/2/62	24.5		60 m	9.5	9.7	0.0039	10.2		32.0	
	24.3		120	8.6	8.8	0.0028	9.3		29.2	
	23.9		240	7.5	7.7	0.0022	8.1		25.4	
	23.7		429	6.9	7.1	0.0016	7.5		23.5	
	23.7		1333	5.4	5.6	0.00098	6.0		18.8	
	23.5		1965	5.0	5.2	0.00077	5.5		17.3	
	24.1		3306	4.8	5.0	0.00062	5.4		16.9	
	23.7		4705	4.5	4.7	0.00053	5.0		15.7	
	24.0		7144	3.8	4.0	0.00046	4.4		13.8	

Hydrometer No.s 5478T and Graduate No. S-1

$W\% = \frac{100}{W_s} \cdot \frac{S_s}{S_s - 1}(R_h + m_t - c_d) =$ 3.14 $(R_h + m_t - c_d)$

Meniscus correction $= c_m =$ 0.2 and respectively

Dispersing agent used Calgon (6%) Amount 10 c.c.

Correction for change in density of liquid due to addition of dispersing agent $= c_d$

$c_d =$ 0.4 and respectively

Specific Gravity of Solids $= G_s$ 2.71

Description of Sample

Method of Preparation

Remarks Check test.
Fat bulb hydrometer.

Initial Moisture Content

Container No.
Wt. Sample Wet + Tare
Wt. Sample Dry + Tare
Wt. Water
Tare Container
Wt. of Dry Soil
Initial Moisture w %

Dry Weight of Sample

Container No.
Wt. Sample (Wet/Dry) + Tare
Tare
Wt. (Wet/Dry) Soil
Dry Weight from Initial
Moisture $= \frac{100 \times \text{Wt. Wet Soil}}{100 + \text{Init. Moist. \%}} =$

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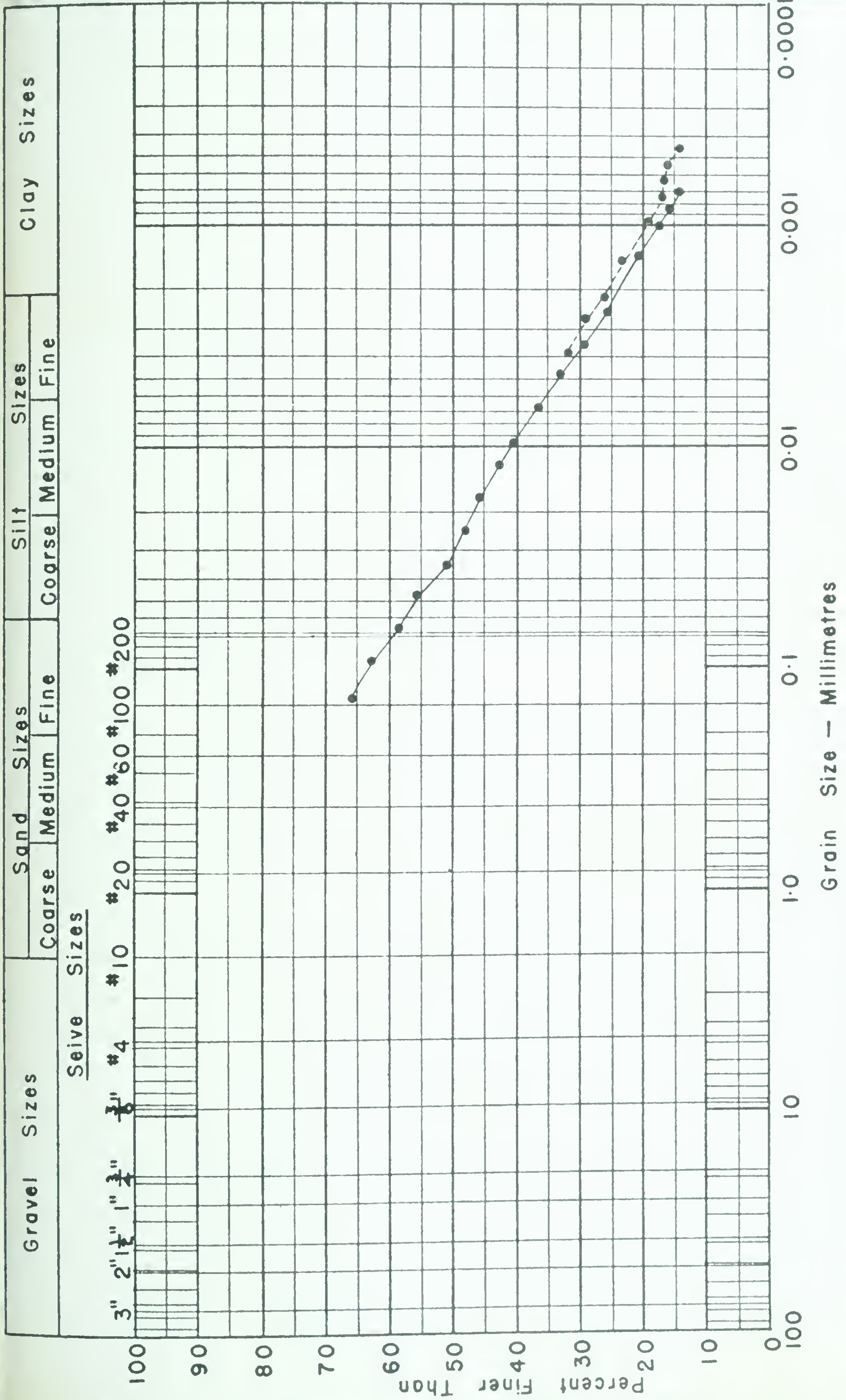
SOIL MECHANICS LABORATORY

GRAIN SIZE CURVE

PROJECT	Thesis		
SITE			
SAMPLE	Edmonton till		
LOCATION			
HOLE		DEPTH	
TECHNICIAN	W.S.	DATE	15/2/62



D_{10} = ____ mm.
D_{60} = ____ mm.
C_u ____

Remarks: Graduate S-1 (check test)
Slim bulb readings ——
Fat bulb readings - - - - - -

Note: M.I.T. Grain Size Scale

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